

# BMJ Open

## The Impact of Temperature Extremes on Mortality in Jinan, China

Journal:	BMJ Open
Manuscript ID	bmjopen-2016-014741
Article Type:	Research
Date Submitted by the Author:	19-Oct-2016
Complete List of Authors:	Han, Jing Liu, Shouqin Zhang, Jun Zhou, Lin Fang, Qiaoling Zhang, Ji Zhang, Ying; University of Sydney, School of Public Health
<b>Primary Subject Heading</b>:	Epidemiology
Secondary Subject Heading:	Public health
Keywords:	PUBLIC HEALTH, EPIDEMIOLOGY, PREVENTIVE MEDICINE

SCHOLARONE™  
Manuscripts

The Impact of Temperature Extremes on Mortality in Jinan, China

Jing Han<sup>1</sup>, Shouqin Liu<sup>1</sup>, Jun Zhang<sup>1</sup>, Lin Zhou<sup>1</sup>, Qiaoling Fang<sup>1</sup>, Ji Zhang<sup>1\*</sup>, Ying Zhang<sup>2,3\*</sup>

<sup>1</sup>Jinan Municipal Center for Disease Control and Prevention, Jinan, China  
<sup>2</sup>Sydney School of Public Health/China Studies Center, The University of Sydney, Sydney, Australia  
<sup>3</sup>School of Public Health/Climate and Health Research Center, Shandong University, Shandong, China

\* Corresponding authors. Tel.: +86 531 81278866; Tel: +61 2 91141417  
E-mail addresses: zhangji1967@163.com (J.Zhang), ying.zhang@sydney.edu.au (Y. Zhang)

**Objective:** To investigate the relationship between temperature extremes and daily number of deaths in Jinan, a temperate city in northern China.  
**Methods:** Data of daily number of deaths and meteorological variables over the period of 2011-2014 were collected. Cold spell/ Heat wave were defined as  $\geq 3$  consecutive days with mean temperature  $\leq 5$ th percentile or  $\geq 95$ th percentile, respectively. We applied a time-series adjusted Poisson regression to assess the effects of extreme temperature on deaths.  
**Results:** There were 152150 non-accidental deaths over the study period in Jinan, among which 87607 persons died of cardiovascular disease, 11690 of respiratory disease, 33001 of stroke disease and 6624 of COPD disease. Cold spell significantly increased the risk of deaths due to non-accidental (RR: 1.08, 95%CI: 1.06-1.11), cardiovascular (RR: 1.06, 95%CI: 1.03-1.10), respiratory (RR: 1.19, 95%CI: 1.11-1.27), stroke (RR: 1.11, 95%CI: 1.06-1.17) and COPD (RR: 1.27, 95%CI: 1.16-1.38). Heat wave was most pronounced for deaths of non-accidental (RR: 1.02, 95%CI: 1.00-1.05), cardiovascular (RR: 1.03, 95%CI: 1.00-1.06) and stroke (RR: 1.06, 95%CI: 1.00-1.13). The elderly were more vulnerable during heat wave exposure. The vulnerability to cold spell was for the whole population regardless of age and gender.  
**Conclusions:** Both cold spell and heat wave have increased the risk of death in Jinan, China.  
**Key words:** Temperature extremes; Mortality; Poisson regression; Time series  
**Word count:** 2182

Strengths and limitations of this study

We focus on the impact of temperature extremes (cold spell and heat wave) on mortality and vulnerable populations to temperature extremes.  
Our research provides more data for developing countries to fight against temperature extremes on mortality.  
Our result could be important for public health intervention on people with underlying chronic disease under temperature extremes exposure.  
Ecological bias is inevitable because ecological confounding on an individual level data were not available for analysis.

1. Introduction

The IPCC has already predicted that extreme temperature events will become more frequent and more intense as global mean temperature rises.<sup>1</sup> For example , the heat wave in 1987 of Athens and in 1995 of Chicago caused thousands of deaths.<sup>2</sup> In Europe and Russia, an increase in the occurrence of extreme temperature events has been observed, such as the devastating heat waves in 2003 and 2010.<sup>3-4</sup> Parts of eastern Asia also experienced extremely hot summer in 2010.<sup>5</sup> 2014 North American cold wave event affected parts of Canada and the Eastern United States which broke 100 year low-temperature records in US(<https://www.climate.gov/news-features/event-tracker/polar-vortex-brings-cold-here-and-there-not-everywhere>). In 2008, southern China experienced a severe continuous cold spell of a long duration, with estimated direct

economic losses of more than US \$22.3 billion. This event is considered a once in 50–100 years event.<sup>6</sup> In the summer of 2013, the strongest intensity of heat waves since 1951 occurred in southern China.<sup>7</sup>

Temperature extremes are a threat to human health and are associated with increased mortality risk.<sup>8–9</sup> Temperature-mortality relationship has been noted with the U, V or J shapes with increased mortality at cold and hot temperatures.<sup>10–11</sup> Increasing mortality due to extreme temperatures has been reported in many countries, e.g. Europe, Russia, US, Australia and China.<sup>12–15</sup> There is a lack of studies in developing countries exploring the association between extreme temperature and mortality. Additionally, reported heterogeneity of the effects of extreme temperatures on mortality varies greatly across regions.<sup>16–17</sup> Limited studies have examined the impacts of extreme temperature on mortality in China and many of previous studies were conducted in subtropical zones of southern China.<sup>18</sup>

Jinan, the capital of Shandong province in Eastern China, is located in a warm temperature zone. Being surrounded by mountains on three sides, Jinan has a unique weather condition with hot summers and cold winters.<sup>19</sup> Our previous study in Jinan found that heat waves significantly increased the risk of mortality and caused 24.88 % excess non-accidental deaths.<sup>20</sup> This study uses more recent data to investigate the effect of both heat wave and cold spell on daily number of deaths in Jinan. Furthermore, we have explored vulnerable populations to temperature extremes.

## 2. Materials and Methods

### 2.1. Data collection

Jinan is located at latitude 36° 40'N and longitude 116° 57'E, with six districts, one county-level city, and three counties. Its population was 7067900 in 2014 with an urban population of 4693700 (Shandong Provincial Statistical Yearbook 2015). Jinan has a temperate climate with four well-defined seasons. The city is dry and nearly rainless in spring, hot and rainy in summer, crisp in autumn and dry and cold in winter. The average annual temperature is 14.70 °C and average total annual rainfall is 670 mm (China Meteorological Administration). Due to the mountains to the south of the city, temperature inversions are common, occurring on about 200 days per year.

Mortality data were obtained from the China Information System for Death Register and the Report of Jinan Municipal Centre for Disease Control and Prevention from 1 January 2011 to 31 December 2014. The mortality data were from ten administrative divisions. We classified non-accidental mortality according to the International Classification of Diseases, 10th revision (ICD-10 codes A00–R99). Chronic Obstructive Pulmonary Disease (COPD) (ICD-10 codes J40–J44, J47), cardiovascular mortality (ICD-10 codes I00–I99), respiratory mortality (ICD-10 codes J00–J99) and stroke (ICD-10 codes I60–I69) were examined separately.

Daily meteorological data over the same period, including daily maximum, mean, and minimum temperature and relative humidity, were obtained from the China Meteorological Data Sharing Service System (CMDSSS). We did not include air pollution levels in our model due to data unavailability.

### 2.2. Data analysis

#### 2.2.1. Relationship between daily number of deaths and overall daily mean temperatures

A descriptive analysis was performed to understand the time-series characteristics of the daily number of deaths and meteorological variables over the study period. Given that previous studies have reported a non-linear relationship between temperature and mortality, non-parametric Spearman correlation analysis was performed. Cross-correlation analysis was also performed with relevant lag values given the potential lagged effect of temperature.

#### 2.2.2. Relationship between daily number of deaths and temperature extremes

Analysis of temperature extremes was restricted to the winter seasons (November–March) and summer seasons (May–August) in 2011–2014 in this study. Heat wave was defined as a period of at least 3 consecutive days

with daily mean temperature above the 95th percentile (29.0 °C) from May to August during the study period; cold spell was defined as a period of at least 3 consecutive days with daily mean temperatures below the 5th percentile (-3.8°C) from November to March during the study period.

Independent-sample t test was used to compare the difference of the average number of non-accidental deaths and cause-specific deaths between the cold spell/heat wave exposure days and non- exposure days. Time-series adjusted Poisson regression was applied to quantify the impacts of cold spell/heat wave on daily number of deaths. Long-term trend and seasonal various, day of week, relative humidity, ambient temperature and autocorrelation were controlled in the model as confounders.

All statistical tests were two-sided and *p*-values of less than 0.05 were considered statistically significant. Stata12 were used for the analysis.

3. Results

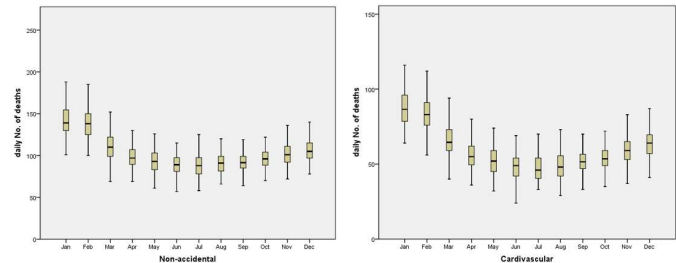
3.1. Relationship between daily number of deaths and overall temperature

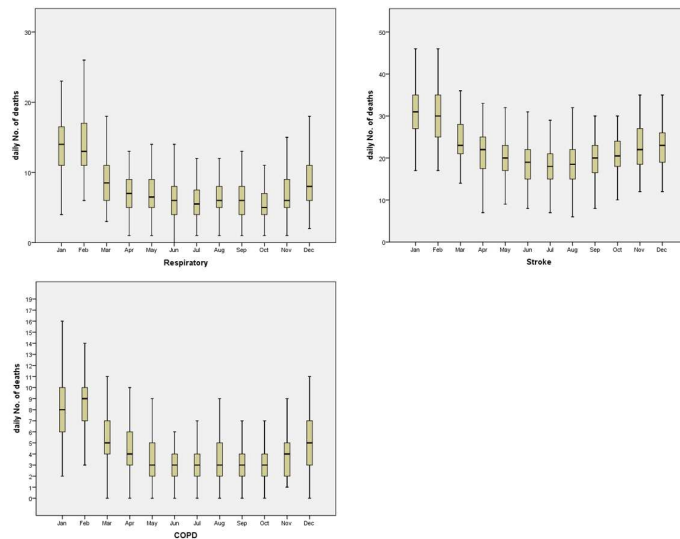
There were 152150 total non-accidental deaths over the study period in Jinan; among which 87607 persons (57.5%) died of cardiovascular disease, 11690 (7.7%) of respiratory disease, 33001 (21.7%) of stroke disease and 6624 (4.3%) of COPD disease. The average daily number of deaths observed was 104.1for non-accidental, 59.9 for cardiovascular, 8.0 for respiratory, 22.6 for stroke and 4.5 for COPD. The average daily mean temperature and mean relative humidity were 14.7 °C (range: -9.4 °C, 34 °C) and 55% (range: 13%, 100.0%), respectively. The 5th and 95th percentiles of temperature were -3.6 °C and 29°C, respectively (Table 1). Additionally, a clear seasonal distribution of daily number of deaths was observed for all categories of mortality with most cases occurring in winter (December-February) and lowest cases in summer (June-August) (Figure.1).

Table1 Summary of the daily number of deaths and weather conditions in Jinan, China, 2011-2014

variables	mean	STD	minimu m	5th percentile	95th percentile	maximu m
<b>Death</b>						
Non-accidental	104.1	22.4	57	75	149	210
Cardiovascular	59.9	16.5	24	38	93	130
Respiratory	8	4.1	0	3	16	26
Stroke	22.6	6.8	5	13	35	46
COPD	4.5	2.9	0	1	10	19
<b>Weather variables</b>						
Mean temperature	14.7	10.7	-9.4	-3.6	29	34
Mean relative humidity	55	20	13	24	90	100
<b>Temperature(°C)</b>						
Spring(Mar-May)	16	7.4	-8	3.9	26.3	34
Summer(Jun-Aug)	26.5	2.8	16.3	21.6	30.9	33
Fall(Sep-Nov)	15.3	6.3	-8	4.9	23.9	28
Winter(Dec-Feb)	0.6	4.5	-9.4	-6.6	8.5	11.3

Figure.1. Seasonal distribution of daily number of deaths in Jinan, China





The cross-correlation analysis showed that all non-accidental and cause-specific deaths were significantly correlated with mean temperature with lagged effects ranging from 7 to 15 days (Table 2).

**Table2** Cross-correlation between mortality and daily mean temperature in Jinan, China

mortality type	Maximum	<i>p</i>	Lag time(d)
	Coefficient		
Non-accidental	-0.656	0.000	15
Cardiovascular	-0.678	0.000	15
Respiratory	-0.551	0.000	14
Stroke	-0.518	0.000	7
COPD	-0.544	0.000	14

### 3.2. Relationship between daily number of deaths and temperature extremes

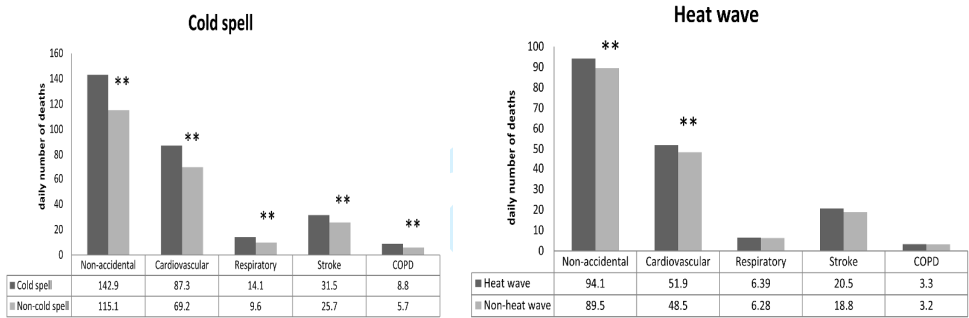
There were seven cold spells ranging from 3 to 6 days in 2011-2014. The lowest minimum temperature and highest minimum temperature was -12.9°C and -3.2°C respectively. Eight heat waves with a total of 39 days were identified during the study period. The lowest maximum temperature and highest maximum temperature was 33.1°C and 39.1°C respectively (Table 3).

**Table3** Characteristics of cold spells and heat waves in Jinan, China

Cold spells					
Year	Date of start	Duration(d)	Lowest Minimum temperature(°C)	Highest Minimum temperature(°C)	Maximum temperature(°C)
2011	Jan14	6	-11.6	-3.2	3
	Jan22	3	-9	-4.5	5.4
2012	Jan20	5	-10.7	-3.4	4
	Feb1	3	-10.4	-6.1	4.8
	Dec23	4	-11.8	-9.3	0
2013	Jan2	4	-12.9	-9.5	5
2014	Feb9	3	-11.2	-6.8	1.3
Heat waves					
Year	Date of start	Duration(d)	Lowest Maximum temperature(°C)	Highest Maximum temperature(°C)	Minimum temperature(°C)
2011	July22	3	33.4	36.8	25.7
2012	June 17	6	34.7	36.9	22.9

	July 25	6	33.7	36.9	24.7
2013	July6	3	34.5	37.2	22.2
	Aug 4	4	33.1	35.6	22.2
	Aug 11	6	34.6	38.2	21.0
2014	May27	5	36	39.1	20.7
	July 16	6	33.4	37.6	24

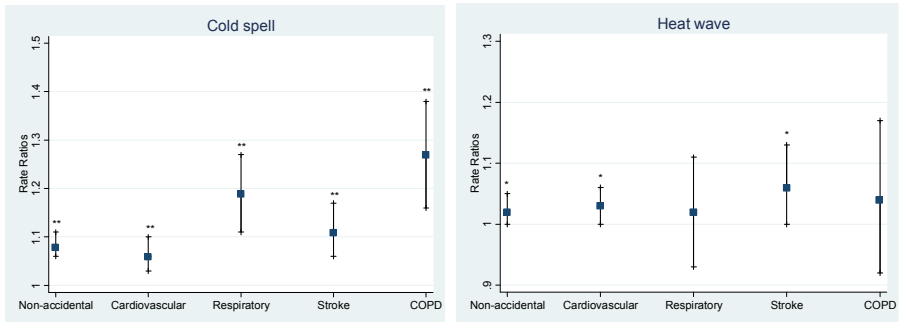
There were 72416 total non-accidental deaths during winter seasons over the study period in Jinan; among which 43698 persons (60.3%) died of cardiovascular disease, 6291 (8.6%) of respiratory disease, 15973 (22.1%) of stroke disease and 3786(5.2%) of COPD disease. A total number of 44729 non-accidental deaths were reported during summer seasons over the study period, among which deaths of cardiovascular disease accounted for 54.4 % (24369), 6.9% (3106) for respiratory disease, 21.1 % (9423) for stroke disease and 3.5 % (1607) for COPD disease. Both cold spell and heat wave were associated with increased mortalities. Cold spell were statistically significant for all examined deaths. Heat wave was most pronounced for non-accidental and cardiovascular mortality but not for the others (Figure 2).



\*\*p < 0.01

**Figure.2.** Comparison of the average daily number of deaths between cold spell/heat wave days and non-exposure days

The Poisson regression models showed that cold spell caused a significant increase in mortality risk of non-accidental (RR1.08, 95%CI: 1.06-1.11), cardiovascular (RR1.06, 95%CI: 1.03-1.10), respiratory (RR1.19, 95%CI: 1.11-1.27), stroke (RR1.11, 95%CI: 1.062-1.17) and COPD (RR1.27, 95%CI: 1.16-1.38), the risk of deaths from non-accidental (RR1.02, 95%CI: 1.00-1.05), cardiovascular (RR1.03, 95%CI: 1.00-1.06) and stroke (RR1.06, 95%CI: 1.00-1.13) also had a significant increase due to heat waves. Deaths of respiratory (RR1.02, 95%CI: 0.93-1.11) and COPD (RR1.04, 95%CI: 0.92-1.17) also increased during the heat waves, but the impact was not statistically significant (Figure 3).



**Figure.3** RR of cold spells and heat waves on daily number of deaths in Jinan, China

Rate ratios (RR) were calculated as ratios between the death numbers in the cold spell/heat wave days and in the non-cold spell/non-heat wave days

\* $p < 0.05$ , \*\* $p < 0.01$

Cold spell significantly increased risk of non-accidental mortality on both genders and age groups. Heat waves increased risk on both genders. The risk of mortality in elderly people (over 65 years) increased statistically during heat waves, but not in  $\leq 64$  years age group (Table 4).

**Table 4** Gender and age specific risk of cold spells and heat waves on total non-accidental mortality in Jinan, China

Exposure period	RR of cold spell (95% CI)	RR of heat wave (95% CI)
Gender		
Male	1.09 (1.06–1.12) **	1.03 (1.00–1.07) *
Female	1.12 (1.08–1.16) **	1.04 (1.00–1.07) *
Age		
0–64	1.14 (1.09–1.19) **	0.97 (0.93–1.02)
$\geq 65$	1.08 (1.06–1.11) **	1.03 (1.01–1.06) **

\* $p < 0.05$ , \*\* $p < 0.01$

#### 4. Discussion

In this study, we have examined the effects of temperature extremes including both cold spell and heat wave on deaths in Jinan, China from 2011 to 2014.

For heat wave, increased risk of deaths has been found for non-accidental, cardiovascular and stroke mortality. Our result has proved our previous heat wave-related mortality study. Moreover, the elderly above 65 years have been found to be more vulnerable during heat waves exposure. The result is consistent with previous studies in Europe, Latin America and China.<sup>21–23</sup> The underlying factors of the vulnerability are both social and medical. An aging society means higher prevalence of chronic and degenerative diseases. For the elderly, their physiological responses to environment decreased along aging and poor medication interacts with thermoregulation. China is facing the challenges of a rapid growth in the number of old people with the largest elderly population in the world. In Jinan, the elderly above 65 was 750,000 which account for 12.31% of population by the end of the year 2014. Giving the large aging population in Jinan, this study has public health implication on improving the public health service for aging people including public health practitioner training, necessary infrastructure for local health agency and health education to respond to temperature extremes especially for heat waves efficiently.

Cold spell has significantly increased risk of death compared to non-cold spell periods. This finding is consistent with previous studies in Europe and Russia. In our study, the significant effects of cold spell were identified on deaths of non-accidental, cardiovascular, respiratory, stroke and COPD. However, in a study of the Eurowinter Group, cold effect was found for respiratory causes but not for cardiovascular disease and ischemic heart disease in warmer countries.<sup>24</sup> In China, a thirty-six communities study found more pronounced cold spell effect for respiratory mortality than for cardiovascular or cerebrovascular mortality.<sup>6</sup> However, a stronger cold effect on cardiovascular disease compared with respiratory mortality was observed in US and Ireland.<sup>25–26</sup> In a recent study conducted a meta-analysis showed cold spell was associated with increased mortality from all non-accidental causes, especially from cardiovascular and respiratory diseases.<sup>27</sup> Our result could be important for public health intervention on people with underlying chronic disease such as cardiovascular, respiratory, stroke and COPD diseases by addressing behavioral risk factors in winter season. Besides, there is a need for specific cold spell prevention plans for public health authority in Jinan, which would enable mortality attributable to low temperatures to be reduced.

1  
2  
3  
4  
5  
6  
7  
8  
9  
10  
11  
12  
13  
14  
15  
16  
17  
18  
19  
20  
21  
22  
23  
24  
25  
26  
27  
28  
29  
30  
31  
32  
33  
34  
35  
36  
37  
38  
39  
40  
41  
42  
43  
44  
45  
46  
47  
48  
49  
50  
51  
52  
53  
54  
55  
56  
57  
58  
59  
60

Climate change, particularly global warming has led to heat and heat wave being a special focus with climate on human health. Cold spell, however, have been given less attention by researchers. Studies have reported that significant increases in mortality during cold spell in different sub-population in Bangladesh, Netherlands, Czech and Moscow. Gasparrini et al. found that the attributable deaths were more pronounced for low than for high temperature in a multicountry study.<sup>28</sup> Additionally, a study using data from 15 European cities demonstrated that cold-related mortality is an important public health problem across Europe. It should not be underestimated by public health authorities because of the recent focus on heat-wave episodes.<sup>29</sup> In UK, excess winter mortality has enjoyed prominent status in many aspects of public policy and research.<sup>30</sup> Our finding demonstrated cold spell is as vital as heat waves in Jinan. Climate change will bring more temperature extremes including cold spell. Therefore it's important to develop emergency response plans to fight against extreme temperature related mortality.

Some limitations of the study should be mentioned. First, the data were only from one city, it is difficult to generalize to other cities. Second, we did not control for air pollution, as these data was not available. Results from European studies suggested there is a synergistic effect of air pollution and cold temperatures or heat waves on mortality. Further study needs to be conducted for this issue. Third, ecological bias is inevitable. Ecological confounding on an individual level data were not available for analysis, e.g. more detailed age groups, living conditions, health status and socio-economic status of deceased people.

**5. Conclusions**

Our results provide more evidence regarding the health impacts of extreme temperatures including cold spell and heat wave. Our study suggests that the cold health effect should not be underestimated in Jinan city. An increasing number and intensity of temperature extremes (cold spell and heat wave) will have a deep impact on health. From the point of view of prevention, multi-discipline cooperation aimed at avoiding or diminishing the effects of temperature extremes need to be carried out.

**Conflict of interest**

The authors declare that there is no conflict of interest.

**Contributors**

JH contributed to the study design, data analysis and drafting of the manuscript. SQL and JunZ contributed to data analysis. LZ and QLF collected and managed the data. YZ and JiZ contributed to study design and paper review.

**Ethics statement**

The project has an ethical approval from China Information System for Death Register and the Report of Jinan Municipal Centre for Disease Control and Prevention with the permission to use the data from 1 January 2011 to 31 December 2014.

**Data sharing statement**

No additional data are available.

**References:**

[1] Stocker T. Climate change 2013 :the physical science basis : Working Group I contribution to the Fifth assessment report of the Intergovernmental Panel on Climate Change. 2014;1535.



- [2] Katsouyanni K T D. The 1987 Athens heat wave. *Lancet*. 1998, 352(9127): 573.
- [3] Barriopedro D, Fischer E M, Luterbacher J, et al. The hot summer of 2010: redrawing the temperature record map of Europe. *Sci*. 2011, 332(6026): 220-224.
- [4] Luterbacher J, Dietrich D, Xoplaki E, et al. European seasonal and annual temperature variability, trends, and extremes since 1500. *Sci*. 2004, 303(5663): 1499-1503.
- [5] Lowe R, Ballester J, Creswick J, et al. Evaluating the performance of a climate-driven mortality model during heat waves and cold spells in Europe. *Int J Environ Res Public Health*. 2015, 12(2): 1279-1294.
- [6] Zhou M G, Wang L J, Liu T, et al. Health impact of the 2008 cold spell on mortality in subtropical China: the climate and health impact national assessment study (CHINAs). *Environ Health*. 2014, 13: 60.
- [7] Gu S, Huang C, Bai L, et al. Heat-related illness in China, summer of 2013. *Int J Biometeorol*. 2016, 60(1): 131-137.
- [8] Guo Y, Gasparrini A, Armstrong B, et al. Global variation in the effects of ambient temperature on mortality: a systematic evaluation. *Epidemiol*. 2014, 25(6): 781-789.
- [9] Huang C, Barnett A G, Wang X, et al. The impact of temperature on years of life lost in Brisbane, Australia. *Nat Clim Change*. 2012, 2(4): 265-270.
- [10] Anderson B G, Bell M L. Weather-related mortality: how heat, cold, and heat waves affect mortality in the United States. *Epidemiol*. 2009, 20(2): 205-213.
- [11] Baccini M, Biggeri A, Accetta G, et al. Heat effects on mortality in 15 European cities. *Epidemiol*. 2008, 19(5): 711-719.
- [12] Barriopedro D, Fischer E M, Luterbacher J, et al. The hot summer of 2010: redrawing the temperature record map of Europe. *Sci*. 2011, 332(6026): 220-224.
- [13] De' D F, Leone M, Scortichini M, et al. Changes in the Effect of Heat on Mortality in the Last 20 Years in Nine European Cities. Results from the PHASE Project. *Int J Environ Res Public Health*. 2015, 12(12): 15567-15583.
- [14] Anderson B G, Bell M L. Weather-related mortality: how heat, cold, and heat waves affect mortality in the United States. *Epidemiol*. 2009, 20(2): 205-213.
- [15] Huang C, Chu C, Wang X, et al. Unusually cold and dry winters increase mortality in Australia. *Environ Res*. 2015, 136: 1-7.
- [16] Zhou M G, Wang L J, Liu T, et al. Health impact of the 2008 cold spell on mortality in subtropical China: the climate and health impact national assessment study (CHINAs). *Environ Health*. 2014, 13: 60.
- [17] Gao J, Sun Y, Liu Q, et al. Impact of extreme high temperature on mortality and regional level definition of heat wave: a multi-city study in China. *Sci Total Environ*. 2015, 505: 535-544.
- [18] Ma W, Zeng W, Zhou M, et al. The short-term effect of heat waves on mortality and its modifiers in China: an analysis from 66 communities. *Environ Int*. 2015, 75: 103-109.
- [19] Zhang Y, Bi P, Sun Y, et al. Projected Years Lost due to Disabilities (YLDs) for bacillary dysentery related to increased temperature in temperate and subtropical cities of China. *J Environ Monit*. 2012, 14(2): 510-516.
- [20] Zhang J, Liu S, Han J, et al. Impact of heat waves on nonaccidental deaths in Jinan, China, and associated risk factors. *Int J Biometeorol* 2016, 60(9):1367-75.
- [21] Oudin åström D, Bertil F, Joacim R. Heat wave impact on morbidity and mortality in the elderly population: A review of recent studies. *Maturitas*. 2011, 69(2): 99-105.

1  
2  
3  
4  
5  
6  
7  
8  
9  
10  
11  
12  
13  
14  
15  
16  
17  
18  
19  
20  
21  
22  
23  
24  
25  
26  
27  
28  
29  
30  
31  
32  
33  
34  
35  
36  
37  
38  
39  
40  
41  
42  
43  
44  
45  
46  
47  
48  
49  
50  
51  
52  
53  
54  
55  
56  
57  
58  
59  
60

[22] Zeng W, Lao X, Rutherford S, et al. The effect of heat waves on mortality and effect modifiers in four communities of Guangdong Province, China. *Sci Total Environ*. 2014, 482-483: 214-221.

[23] Ma W, Zeng W, Zhou M, et al. The short-term effect of heat waves on mortality and its modifiers in China: An analysis from 66 communities. *Environ Inter*. 2015, 75: 103-109.

[24] Cold exposure and winter mortality from ischaemic heart disease, cerebrovascular disease, respiratory disease, and all causes in warm and cold regions of Europe. The Eurowinter Group. *Lancet*. 1997, 349(9062): 1341-1346.

[25] Braga A L, Zanobetti A, Schwartz J. The effect of weather on respiratory and cardiovascular deaths in 12 U.S. cities. *Environ Health Perspect*. 2002, 110(9): 859-863.

[26] Zeka A, Browne S, Mcavoy H, et al. The association of cold weather and all-cause and cause-specific mortality in the island of Ireland between 1984 and 2007. *Environ Health*. 2014, 13: 104.

[27] Rytö N R, Guo Y, Jaakkola J J. Global Association of Cold Spells and Adverse Health Effects: A Systematic Review and Meta-Analysis. *Environ Health Perspect*. 2016, 124(1): 12-22.

[28] Gasparrini A, Guo Y, Hashizume M, et al. Mortality risk attributable to high and low ambient temperature: a multicountry observational study. *Lancet*. 2015, 386(9991): 369-375.

[29] Analitis A, Katsouyanni K, Biggeri A, et al. Effects of cold weather on mortality: results from 15 European cities within the PHEWE project. *Am J Epidemiol*. 2008, 168(12): 1397-1408.

[30] Liddell C, Morris C, Thomson H, et al. Excess winter deaths in 30 European countries 1980 – 2013: a critical review of methods. *J Public Health*. 2015: v184.

## Research checklist

	Item No	Recommendation
<b>Title and abstract</b>	1	(a) P1
		(b) P1
<b>Introduction</b>		
Background/rationale	2	P1
Objectives	3	P1
<b>Methods</b>		
Study design	4	P2
Setting	5	P2
Participants	6	P2
		P2
Variables	7	P2
Data sources/ measurement	8*	P2
Bias	9	NA
Study size	10	P2
Quantitative variables	11	P2
Statistical methods	12	P2
		P2
		P2
		P2
		P2

Continued on next page

<b>Results</b>		
Participants	13*	(a) P3
		(b) NA
		(c) NA
Descriptive data	14*	(a) NA
		(b) NA
		(c) NA
Outcome data	15*	P3
Main results	16	P3–6
		P3–6
		P3–6
Other analyses	17	NA
<b>Discussion</b>		
Key results	18	P6
Limitations	19	P7
Interpretation	20	P7
Generalisability	21	P7
<b>Other information</b>		
Funding	22	NA

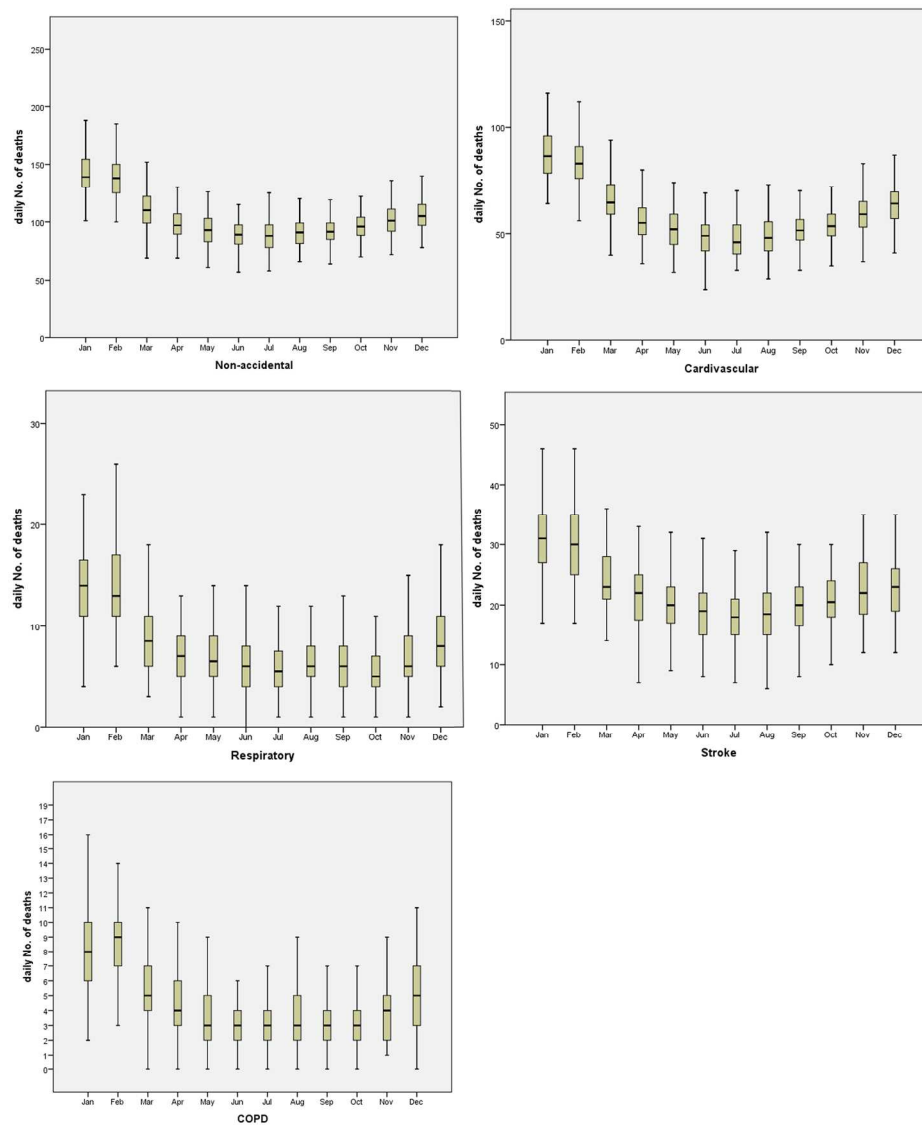
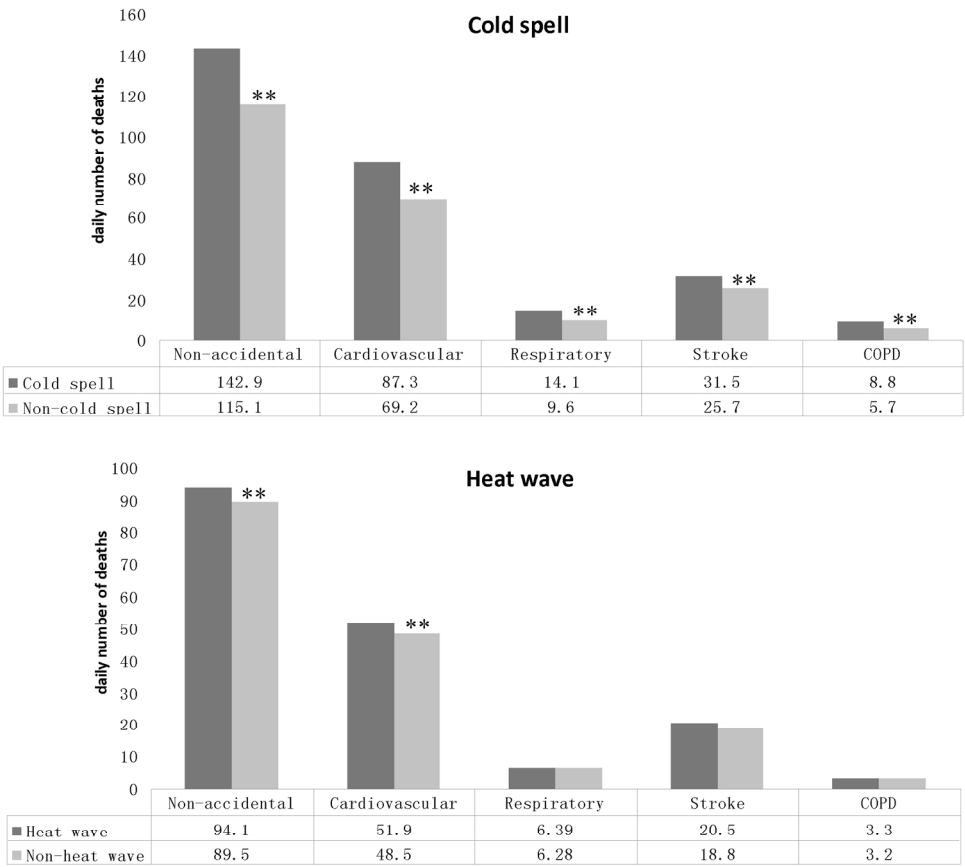
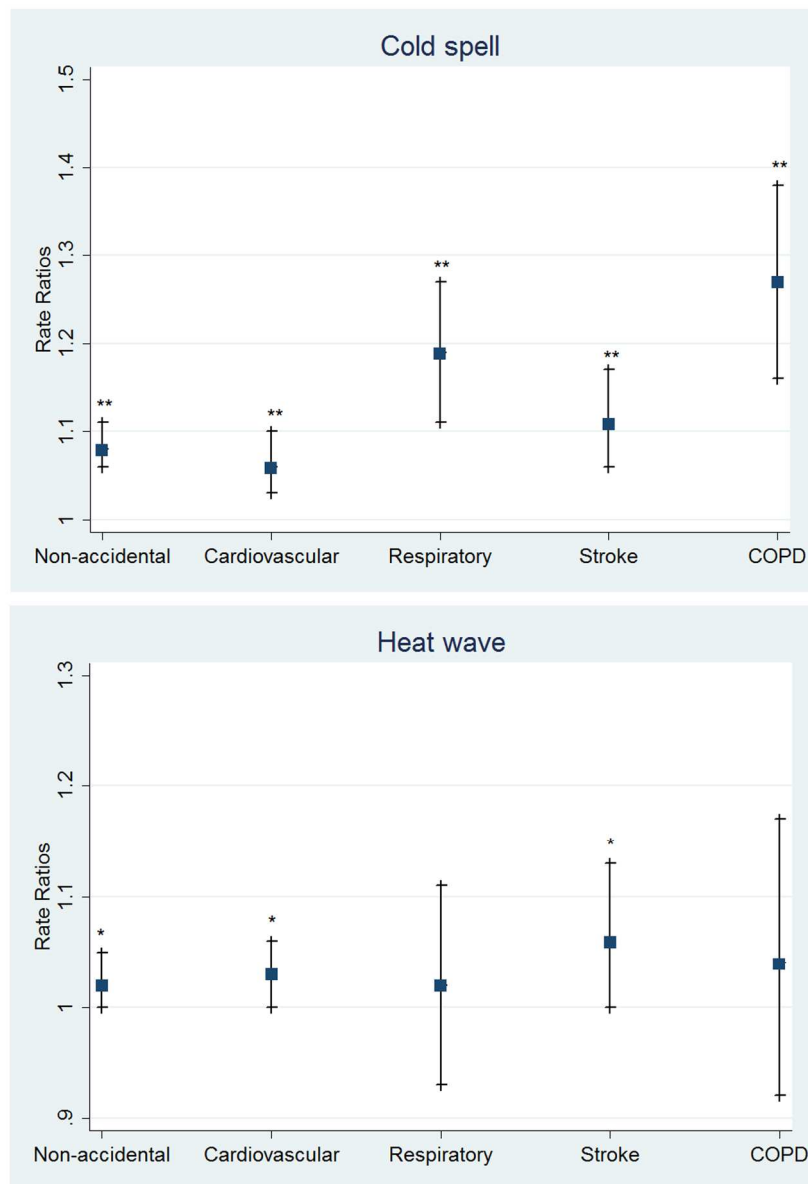


Figure.1. Seasonal distributio  
173x219mm (300 x 300 DPI)



\*\*p < 0.01  
Figure.2. Comparison of the av  
173x199mm (300 x 300 DPI)



\*p < 0.05, \*\*p < 0.01  
Figure.3 RR of cold spells and  
160x219mm (300 x 300 DPI)

# BMJ Open

## The Impact of Temperature Extremes on Mortality : a time-series study in Jinan, China

Journal:	<i>BMJ Open</i>
Manuscript ID	bmjopen-2016-014741.R1
Article Type:	Research
Date Submitted by the Author:	25-Jan-2017
Complete List of Authors:	Han, Jing Liu, Shouqin Zhang, Jun Zhou, Lin Fang, Qiaoling Zhang, Ji Zhang, Ying; University of Sydney, School of Public Health
<b>Primary Subject Heading</b>:	Epidemiology
Secondary Subject Heading:	Public health
Keywords:	PUBLIC HEALTH, EPIDEMIOLOGY, PREVENTIVE MEDICINE

SCHOLARONE™  
Manuscripts



The Impact of Temperature Extremes on Mortality: a time-series study in Jinan, China

Jing Han<sup>1</sup>, Shouqin Liu<sup>1</sup>, Jun Zhang<sup>1</sup>, Lin Zhou<sup>1</sup>, Qiaoling Fang<sup>1</sup>, Ji Zhang<sup>1\*</sup>, Ying Zhang<sup>2,3\*</sup>

<sup>1</sup>Jinan Municipal Center for Disease Control and Prevention, Jinan, China  
<sup>2</sup>Sydney School of Public Health/China Studies Center, The University of Sydney, Sydney, Australia  
<sup>3</sup>School of Public Health/Climate and Health Research Center, Shandong University, Shandong, China

\* Corresponding authors. Tel.: +86 531 81278866; Tel: +61 2 91141417

E-mail addresses: zhangji1967@163.com (J.Zhang), ying.zhang@sydney.edu.au (Y. Zhang)

**Objective:** To investigate the relationship between temperature extremes and daily number of deaths in Jinan, a temperate city in northern China.

**Methods:** Data of daily number of deaths and meteorological variables over the period of 2011-2014 were collected. Cold spell/ Heat wave were defined as  $\geq 3$  consecutive days with mean temperature  $\leq 5$ th percentile or  $\geq 95$ th percentile, respectively. We applied a time-series adjusted Poisson regression to assess the effects of extreme temperature on deaths.

**Results:** There were 152150 non-accidental deaths over the study period in Jinan, among which 87607 persons died of cardiovascular disease, 11690 of respiratory disease, 33001 of stroke disease and 6624 of COPD disease. Cold spell significantly increased the risk of deaths due to non-accidental (RR: 1.08, 95%CI: 1.06-1.11), cardiovascular (RR: 1.06, 95%CI: 1.03-1.10), respiratory (RR: 1.19, 95%CI: 1.11-1.27), stroke (RR: 1.11, 95%CI: 1.06-1.17) and COPD (RR: 1.27, 95%CI: 1.16-1.38). Heat wave was most pronounced for deaths of non-accidental (RR: 1.02, 95%CI: 1.00-1.05), cardiovascular (RR: 1.03, 95%CI: 1.00-1.06) and stroke (RR: 1.06, 95%CI: 1.00-1.13). The elderly were more vulnerable during heat wave exposure. The vulnerability to cold spell was for the whole population regardless of age and gender.

**Conclusions:** Both cold spell and heat wave have increased the risk of death in Jinan, China.

**Key words:** Temperature extremes; Mortality; Poisson regression; Time series

**Word count:** 3426

Strengths and limitations of this study

This study was the first to examine the effects of both cold spell and heat wave on mortality in China of the study area. A large and recent database with more than 152k mortality data was analyzed to achieve robust results. Analysis of population vulnerability based on age and gender was also performed. However, ecological bias based on population data was inevitable. Data on air pollution were not available for the analysis. Generalization of the findings should also be cautious, given data from one city were included in the study

1. Introduction

The IPCC has already predicted that extreme temperature events will become more frequent and more intense as global mean temperature rises.<sup>1</sup> For example , the heat wave in 1987 of Athens and in 1995 of Chicago caused thousands of deaths.<sup>2</sup> In Europe and Russia, an increase in the occurrence of extreme temperature events has been observed, such as the devastating heat waves in 2003 and 2010.<sup>3-4</sup> Parts of eastern Asia also experienced extremely hot summer in 2010.<sup>5</sup> 2014 North American cold wave event affected parts of Canada and the Eastern United States which broke 100 year low-temperature records in US(<https://www.climate.gov/news-features/event-tracker/polar-vortex-brings-cold-here-and-there-not-everywhere>).

In 2008, southern China experienced a severe continuous cold spell of a long duration, with estimated direct economic losses of more than US \$22.3 billion. This event is considered a once in 50–100 years event.<sup>6</sup> In the summer of 2013, the strongest intensity of heat waves since 1951 occurred in southern China.<sup>7</sup>

Temperature extremes are a threat to human health and are associated with increased mortality risk.<sup>8–9</sup> Temperature-mortality relationship has been noted with the U, V or J shapes with increased mortality at cold and hot temperatures.<sup>10–11</sup> Increasing mortality due to extreme temperatures has been reported in many countries, e.g. Europe, Russia, US, Australia and China.<sup>12–13</sup> There is a lack of studies in developing countries exploring the association between extreme temperature and mortality. Additionally, reported heterogeneity of the effects of extreme temperatures on mortality varies greatly across regions.<sup>6, 14</sup> Limited studies have examined the impacts of extreme temperature on mortality in China and many of previous studies were conducted in subtropical zones of southern China.<sup>15</sup>

Jinan, the capital of Shandong province in Eastern China, is located in a warm temperature zone. Being surrounded by mountains on three sides, Jinan has a unique weather condition with very hot summers and cold winters.<sup>16</sup> However, there has been not a clear picture on the effects of both extreme cold and hot temperatures on mortality in the city, which was not included in the previous publication on weather-mortality in 66 communities in China either.<sup>15</sup> Our previous study in Jinan has found that heat waves significantly increased the risk of mortality and caused 24.88 % excess non-accidental deaths.<sup>17</sup> This study used more recent data to investigate the effect of both heat wave and cold spell on daily number of deaths in Jinan. Furthermore, we have explored vulnerable populations to temperature extremes.

## 2. Materials and Methods

### 2.1. Data collection

Jinan is located at latitude 36° 40'N and longitude 116° 57'E, with six districts, one county-level city, and three counties. Its population was 7067900 in 2014 with an urban population of 4693700 (Shandong Provincial Statistical Yearbook 2015). Jinan has a temperate climate with four well-defined seasons. The city is dry and nearly rainless in spring, hot and rainy in summer, crisp in autumn and dry and cold in winter. The average annual temperature is 14.70 °C and average total annual rainfall is 670 mm (China Meteorological Administration). Due to the mountains to the south of the city, temperature inversions are common, occurring on about 200 days per year.

Mortality data were obtained from the China Information System for Death Register and the Report of Jinan Municipal Centre for Disease Control and Prevention from 1 January 2011 to 31 December 2014. The mortality data were from ten administrative divisions. We classified non-accidental mortality according to the International Classification of Diseases, 10th revision (ICD-10 codes A00–R99). Chronic Obstructive Pulmonary Disease (COPD) (ICD-10 codes J40–J44, J47), cardiovascular mortality (ICD-10 codes I00–I99), respiratory mortality (ICD-10 codes J00–J99) and stroke (ICD-10 codes I60–I69) were examined separately.

Daily meteorological data over the same period, including daily maximum, mean, and minimum temperature and relative humidity, were obtained from the China Meteorological Data Sharing Service System (CMDSSS). We did not include air pollution levels in our model due to data unavailability.

### 2.2. Data analysis

#### 2.2.1. Relationship between daily number of deaths and overall daily mean temperatures

A descriptive analysis was performed to understand the time-series characteristics of the daily number of deaths and meteorological variables over the study period. Given that previous studies have reported a non-linear relationship between temperature and mortality, non-parametric Spearman correlation analysis was performed. Cross-correlation analysis was also performed with relevant lag values given the potential lagged effect of temperature.

2.2.2. Relationship between daily number of deaths and temperature extremes

Analysis of temperature extremes was restricted to the winter seasons (November-March) and summer seasons (May-August) in 2011-2014 in this study. Heat wave was defined as a period of at least 3 consecutive days with daily mean temperature above the 95th percentile (29.0 °C) from May to August during the study period; cold spell was defined as a period of at least 3 consecutive days with daily mean temperatures below the 5th percentile (-3.8°C) from November to March during the study period. We did not investigate the risks due to different characteristics of heat waves and cold spells due to the similar features of these waves observed from this study area.

Independent-sample t test was used to compare the difference of the average number of non-accidental deaths and cause-specific deaths between the cold spell/heat wave exposure days and non- exposure days. Time-series adjusted Poisson regression was applied to quantify the impacts of cold spell/heat wave on daily number of deaths at different lag days. Contributing factors such as long-term and seasonal trends, day of week (DOW), relative humidity (RH) and ambient temperature were controlled in the model as potential confounders. No over-dispersion was detected in our data, and the model used in the analysis can be described as:

$$\text{Log}[E(Y_t)] = \alpha + \beta T_{\text{min}_t} + \eta \text{DOW}_t + \gamma \text{Strata}_t + \lambda \text{RH}_t + \delta \text{ED}_t$$

where t is the day of the observation;  $Y_t$  is the observed daily death counts on day t;  $\alpha$  is the intercept;  $T_{\text{min}_t}$  is mean temperature on day t, and  $\beta$  is vector of coefficients; DOW is day of the week on day t, and  $\eta$  is vector of coefficients;  $\text{Strata}_t$  is a categorical variable of the year and calendar month used to control for season and trends, and  $\gamma$  is vector of coefficients. RH is relative humidity on day t, and  $\lambda$  is vector of coefficients; ED(exposure days)t is a binary variable that is “1” if day t was a extreme temperature exposure days(cold spell/heat wave), and  $\delta$  is the coefficient.

Relative Risks were estimated by the regression. Population vulnerability was examined based on age and gender of deceased cases.

All statistical tests were two-sided and p-values of less than 0.05 were considered statistically significant. Stata12 were used for the analysis.

3. Results

3.1. Relationship between daily number of deaths and overall temperature

There were 152150 total non-accidental deaths over the study period in Jinan; among which 87607 persons (57.5%) died of cardiovascular disease, 11690 (7.7%) of respiratory disease, 33001 (21.7%) of stroke disease and 6624 (4.3%) of COPD disease. The average daily number of deaths observed was 104.1for non-accidental, 59.9 for cardiovascular, 8.0 for respiratory, 22.6 for stroke and 4.5 for COPD. The average daily mean temperature and mean relative humidity were 14.7 °C (range: -9.4 °C, 34 °C) and 55% (range: 13%, 100.0%), respectively. The 5th and 95th percentiles of temperature were -3.6 °C and 29°C, respectively (Table 1). Additionally, a clear seasonal distribution of daily number of deaths was observed for all categories of mortality with most cases occurring in winter (December-February) and lowest cases in summer (June-August) (Figure.1).

**Table1** Summary of the daily number of deaths and weather conditions in Jinan, China, 2011-2014

variables	mean	STD	minimu m	5th percentile	95th percentile	maximu m
<b>Death</b>						
Non-accidental	104.1	22.4	57	75	149	210
Cardiovascular	59.9	16.5	24	38	93	130
Respiratory	8	4.1	0	3	16	26
Stroke	22.6	6.8	5	13	35	46
COPD	4.5	2.9	0	1	10	19
<b>Weather variables</b>						

Mean temperature	14.7	10.7	-9.4	-3.6	29	34
Mean relative humidity	55	20	13	24	90	100
<b>Temperature(°C)</b>						
Spring(Mar-May)	16	7.4	-8	3.9	26.3	34
Summer(Jun-Aug)	26.5	2.8	16.3	21.6	30.9	33
Fall(Sep-Nov)	15.3	6.3	-8	4.9	23.9	28
Winter(Dec-Feb)	0.6	4.5	-9.4	-6.6	8.5	11.3

**Figure.1.** Seasonal distribution of daily number of deaths in Jinan, China

The cross-correlation analysis showed that all non-accidental and cause-specific deaths were significantly correlated with mean temperature with lagged effects ranging from 7 to 15 days (Table 2).

**Table2** Cross-correlation between mortality and daily mean temperature in Jinan, China

mortality type	Maximum Coefficient	<i>p</i>	Lag time(d)
Non-accidental	-0.656	0.000	15
Cardiovascular	-0.678	0.000	15
Respiratory	-0.551	0.000	14
Stroke	-0.518	0.000	7
COPD	-0.544	0.000	14

### 3.2. Relationship between daily number of deaths and temperature extremes

There were seven cold spells ranging from 3 to 6 days in 2011-2014. The lowest minimum temperature and highest minimum temperature was -12.9°C and -3.2°C respectively. Eight heat waves with a total of 39 days were identified during the study period. The lowest maximum temperature and highest maximum temperature was 33.1°C and 39.1°C respectively (Table 3).

**Table3** Characteristics of cold spells and heat waves in Jinan, China

Cold spells					
Year	Date of start	Duration(d)	Lowest Minimum temperature(°C)	Highest Minimum temperature(°C)	Maximum temperature(°C)
2011	Jan14	6	-11.6	-3.2	3
	Jan22	3	-9	-4.5	5.4
2012	Jan20	5	-10.7	-3.4	4
	Feb1	3	-10.4	-6.1	4.8
	Dec23	4	-11.8	-9.3	0
2013	Jan2	4	-12.9	-9.5	5
2014	Feb9	3	-11.2	-6.8	1.3
Heat waves					
Year	Date of start	Duration(d)	Lowest Maximum temperature(°C)	Highest Maximum temperature(°C)	Minimum temperature(°C)
2011	July22	3	33.4	36.8	25.7
2012	June 17	6	34.7	36.9	22.9
	July 25	6	33.7	36.9	24.7
2013	July6	3	34.5	37.2	22.2
	Aug 4	4	33.1	35.6	22.2
	Aug 11	6	34.6	38.2	21.0
2014	May27	5	36	39.1	20.7
	July 16	6	33.4	37.6	24

There were 72416 total non-accidental deaths during winter seasons over the study period in Jinan; among which 43698 persons (60.3%) died of cardiovascular disease, 6291 (8.6%) of respiratory disease, 15973 (22.1%) of stroke disease and 3786(5.2%) of COPD disease. A total number of 44729 non-accidental deaths were reported during summer seasons over the study period, among which deaths of cardiovascular disease accounted for 54.4 % (24369), 6.9% (3106) for respiratory disease, 21.1 % (9423) for stroke disease and 3.5 % (1607) for COPD disease. Both cold spell and heat wave were associated with increased mortalities. Cold spell were statistically significant for all examined deaths. Heat wave was most pronounced for non-accidental and cardiovascular mortality but not for the others (Figure 2).

**Figure.2.** Comparison of the average daily number of deaths between cold spell/heat wave days and non-exposure days

The Poisson regression models showed that cold spell caused a significant increase in mortality risk of non-accidental (RR1.08, 95%CI: 1.06-1.11), cardiovascular (RR1.06, 95%CI: 1.03-1.10), respiratory (RR1.19, 95%CI: 1.11-1.27), stroke (RR1.11, 95%CI: 1.062-1.17) and COPD (RR1.27, 95%CI: 1.16-1.38). The risk of deaths related to heat waves also increased for non-accidental (RR1.02, 95%CI: 1.00-1.05), cardiovascular (RR1.03, 95%CI: 1.00-1.06) and stroke (RR1.06, 95%CI: 1.00-1.13) but not for deaths due to respiratory (RR1.02, 95%CI: 0.93-1.11) and COPD (RR1.04, 95%CI: 0.92-1.17) (Figure 3).

**Figure.3** RR of cold spells and heat waves on daily number of deaths in Jinan, China

Rate ratios (RR) were calculated as ratios between the death numbers in the cold spell/heat wave days and in the non-cold spell/non-heat wave days

\* $p < 0.05$ , \*\* $p < 0.01$

Cold spell significantly increased risk of non-accidental mortality on both genders and age groups. Heat waves increased risk on both genders. The risk of mortality in elderly people (over 65 years) increased statistically during heat waves, but not in  $\leq 64$ years age group (Table 4).

**Table4** Gender and age specific risk of cold spells and heat waves on total non-accidental mortality in Jinan, China

Exposure period	RR of cold spell (95% CI)	RR of heat wave (95% CI)
Gender		
Male	1.09 (1.06-1.12) **	1.03 (1.00-1.07) *
Female	1.12 (1.08-1.16) **	1.04 (1.00-1.07) *
Age		
0-64	1.14 (1.09-1.19) **	0.97 (0.93-1.02)
$\geq 65$	1.08 (1.06-1.11) **	1.03 (1.01-1.06) **

\* $p < 0.05$ , \*\* $p < 0.01$

**4. Discussion**

In this study, we have examined the effects of temperature extremes including both cold spell and heat wave on deaths in Jinan, China from 2011 to 2014. Our results indicate both extreme cold and heat waves could increase the risk of deaths in the study area. The population vulnerability to temperature extremes varies depending on age and gender.

For heat wave, an increased risk of deaths has been found for non-accidental, cardiovascular and stroke mortality. Our result has confirmed the results from our previous study on heat wave and mortality. Moreover, the elderly above 65 years have been found to be more vulnerable during heat waves exposure. The result is consistent

with previous studies in Europe, Latin America and China.<sup>15, 18-19</sup> However, our estimates of increased mortality risk during heat waves are not as high as those from the previous study on temperature and mortality in China.<sup>15</sup> There are several possible reasons for this. First of all, techniques used to estimate increased risks for mortality varied across the studies. We applied a time-series adjusted Poisson regression rather than a time-series regression model combined distributed lag nonlinear model (DLNM) used in Ma's studies. The DLNM can estimate cumulative effect in the existence of delayed contributions. But they used cumulative excess mortality risk of heat wave only at 0-1 lag days. Instead, we have examined the risk at various lag values. Moreover, Jinan often has particularly very hot summer days with unique geographic and environmental situations. Local residents may have developed adaptive behaviors to heat, which could contribute to a reduced mortality risk.

The underlying factors of the vulnerability are both social and medical. An aging society means higher prevalences of chronic and degenerative diseases. For the elderly, their physiological responses to environment decreased along aging and poor medication interacts with thermoregulation. China is facing the challenges of a rapid growth in the number of old people with the largest elderly population in the world. In Jinan, the elderly above 65 was 750,000 which accounted for 12.31% of population by the end of the year 2014. Giving the large aging population in Jinan, this study has public health implication on improving the public health service for aging people in a changing climate.

Cold spell has significantly increased risk of death compared to non-cold spell periods. This finding is consistent with previous studies in Europe and Russia. In our study, the significant effects of cold spell were identified on deaths of non-accidental, cardiovascular, respiratory, stroke and COPD. However, in a study of the Eurowinter Group, cold effect was found for respiratory causes but not for cardiovascular disease and ischemic heart disease in warmer countries.<sup>20</sup> In China, a thirty-six communities study found more pronounced cold spell effect for respiratory mortality than for cardiovascular or cerebrovascular mortality.<sup>6</sup> However, a stronger cold effect on cardiovascular disease compared with respiratory mortality was observed in US and Ireland.<sup>21-22</sup> In a recent study conducted a meta-analysis showed cold spell was associated with increased mortality from all non-accidental causes, especially from cardiovascular and respiratory diseases.<sup>23</sup> Our result could be important for public health intervention on people with underlying chronic disease such as cardiovascular, respiratory, stroke and COPD diseases by addressing behavioral risk factors in winter season. Besides, there is a need for specific cold spell prevention plans for public health authority in Jinan, which would enable mortality attributable to low temperatures to be reduced.

One interesting finding from our study is the higher vulnerability to cold among the younger age group (<65 years) compared with the elderly (over 65 years). The finding sounds different from previous studies that reported older people (over 65 years or 75 years) might be the most vulnerable.<sup>24-25</sup> It indicates that population vulnerability to cold spell could vary depending on various study settings. Similar evidence in Ireland that young adult (18-64 years) with respiratory disease might be the most susceptible to cold related deaths.<sup>24</sup> Kysely's study conducted in the Czech Republic reported cold spells had the greatest effect on young adult men (25-59 years) with CVD.<sup>26</sup> Occupational exposure might attribute to our finding, given that older people tended to stay indoors during cold days, and thus avoided direct exposure to low ambient temperatures. In addition, adaptive behaviors might be more likely taken by older residents in Jinan because of very cold winters in the history. More research is required to identify underlying reasons of the population vulnerability to cold in Jinan. Climate change, particularly global warming has led to heat and heat wave being a special focus with climate on human health. Cold spell, however, have been given less attention by researchers. Studies have reported that significant increases in mortality during cold spell in different sub-population in Bangladesh, Netherlands, Czech and Moscow. Gasparrini et al. found that the attributable deaths were more pronounced for low than for high temperature in a multicountry study.<sup>27</sup> Additionally, a study using data from 15 European cities demonstrated that cold-related



1  
2  
3  
4  
5  
6  
7  
8  
9  
10  
11  
12  
13  
14  
15  
16  
17  
18  
19  
20  
21  
22  
23  
24  
25  
26  
27  
28  
29  
30  
31  
32  
33  
34  
35  
36  
37  
38  
39  
40  
41  
42  
43  
44  
45  
46  
47  
48  
49  
50  
51  
52  
53  
54  
55  
56  
57  
58  
59  
60

mortality is an important public health problem across Europe. It should not be underestimated by public health authorities because of the recent focus on heat-wave episodes.<sup>28</sup> In UK, excess winter mortality has enjoyed prominent status in many aspects of public policy and research.<sup>29</sup> Our finding has demonstrated that cold spell is as vital as heat waves in Jinan.

Given that climate change will bring more temperature extremes including cold spell, our study has public health implications for policy and practice for government at all levels, as well as community capacity building. Specifically, findings of our study can assist in development of adaptive strategies and policies with a focus on identified vulnerable populations in the community, including the refinement of current public health emergency response plans to focus on both very hot and very cold temperatures. It could also inform the development of clinical guidelines and training programs to doctors in order to improve health service during extreme temperature events, with a better understanding of the pathophysiological mechanisms in mediating heat and cold health effects. Building community resilience could also be supported with better preparation to reduce the number of temperature-related deaths. Some limitations of the study should be acknowledged. First, the data were only from one city, generalization of the results to other regions should be cautious. However, we also recognize the importance of local studies to assist decision making for local communities. The lessons learnt from Jinan could provide more evidence for other regions with similar conditions in China. Second, data of air pollution, e.g. ozone, was not available over the study period. In previous studies, the estimated temperature effects were slightly reduced or not changed when air pollution including ozone was controlled for.<sup>10, 25</sup> Some studies also found a potential interaction between temperature and ozone.<sup>30</sup> However, there are also studies suggesting that the effects of air pollution on mortality could be much smaller than the temperature effects.<sup>31-32</sup> Thus, the relationship that we detected between mortality and the temperature extremes might not be substantially confounded by the effects of air pollution. Third, ecological bias based on population data is inevitable. More studies could be conducted when individual level data, e.g. more detailed age groups, living conditions, health status and socio-economic status of deceased people, are available to be able to detect more detailed distribution of population vulnerability.

**Conclusions**

Our results provide more evidence regarding the health impacts of extreme temperatures including cold spell and heat wave. Our study suggests that the cold health effect should not be underestimated in Jinan city. An increasing number and intensity of temperature extremes (cold spell and heat wave) will have a deep impact on health. From the point of view of prevention, multi-discipline cooperation aimed at avoiding or diminishing the effects of temperature extremes need to be carried out.

**Conflict of interest**

The authors declare that there is no conflict of interest.

**Contributors**

JH contributed to the study design, data analysis and drafting of the manuscript. SQL and JZ contributed to data collection, analysis, interpretation of data and wiring the draft. LZ and QLF collected and managed the data sets and contributed to data analysis, manuscript writing and interpretation to policy. YZ and JZ contributed to study design, data analysis and interpretation of results, as well as manuscript writing and dissemination of findings to stakeholders.

**Ethics statement**

The project has an ethical approval from China Information System for Death Register and the Report of Jinan Municipal Centre for Disease Control and Prevention with the permission to use the data from 1 January 2011 to 31 December 2014.

**Data sharing statement**

No additional data are available.

## References:

- [1] Stocker T. Climate change 2013: the physical science basis: Working Group I contribution to the Fifth assessment report of the Intergovernmental Panel on Climate Change. 2014:1535.
- [2] Katsouyanni K T D. The 1987 Athens heat wave. *Lancet*. 1998, 351(9126): 573.
- [3] Barriopedro D, Fischer E M, Luterbacher J, et al. The hot summer of 2010: redrawing the temperature record map of Europe. *Sci*. 2011, 332(6026): 220-224.
- [4] Luterbacher J, Dietrich D, Xoplaki E, et al. European seasonal and annual temperature variability, trends, and extremes since 1500. *Sci*. 2004, 303(5663): 1499-1503.
- [5] Lowe R, Ballester J, Creswick J, et al. Evaluating the performance of a climate-driven mortality model during heat waves and cold spells in Europe. *Int J Environ Res Public Health*. 2015, 12(2): 1279-1294.
- [6] Zhou M G, Wang L J, Liu T, et al. Health impact of the 2008 cold spell on mortality in subtropical China: the climate and health impact national assessment study (CHINAs). *Environ Health*. 2014, 13: 60.
- [7] Gu S, Huang C, Bai L, et al. Heat-related illness in China, summer of 2013. *Int J Biometeorol*. 2016, 60(1): 131-137.
- [8] Guo Y, Gasparrini A, Armstrong B, et al. Global variation in the effects of ambient temperature on mortality: a systematic evaluation. *Epidemiol*. 2014, 25(6): 781-789.
- [9] Huang C, Barnett A G, Wang X, et al. The impact of temperature on years of life lost in Brisbane, Australia. *Nat Clim Change*. 2012, 2(4): 265-270.
- [10] Anderson B G, Bell M L. Weather-related mortality: how heat, cold, and heat waves affect mortality in the United States. *Epidemiol*. 2009, 20(2): 205-213.
- [11] Baccini M, Biggeri A, Accetta G, et al. Heat effects on mortality in 15 European cities. *Epidemiol*. 2008, 19(5): 711-719.
- [12] De' D F, Leone M, Scortichini M, et al. Changes in the Effect of Heat on Mortality in the Last 20 Years in Nine European Cities. Results from the PHASE Project. *Int J Environ Res Public Health*. 2015, 12(12): 15567-15583.
- [13] Huang C, Chu C, Wang X, et al. Unusually cold and dry winters increase mortality in Australia. *Environ Res*. 2015, 136: 1-7.
- [14] Gao J, Sun Y, Liu Q, et al. Impact of extreme high temperature on mortality and regional level definition of heat wave: a multi-city study in China. *Sci Total Environ*. 2015, 505: 535-544.
- [15] Ma W, Zeng W, Zhou M, et al. The short-term effect of heat waves on mortality and its modifiers in China: an analysis from 66 communities. *Environ Int*. 2015, 75: 103-109.
- [16] Zhang Y, Bi P, Sun Y, et al. Projected Years Lost due to Disabilities (YLDs) for bacillary dysentery related to increased temperature in temperate and subtropical cities of China. *J Environ Monit*. 2012, 14(2): 510-516.
- [17] Zhang J, Liu S, Han J, et al. Impact of heat waves on nonaccidental deaths in Jinan, China, and associated risk factors. *Int J Biometeorol* 2016, 60(9):1367-75.
- [18] Oudin åström D, Bertil F, Joacim R. Heat wave impact on morbidity and mortality in the elderly population: A review of recent studies. *Maturitas*. 2011, 69(2): 99-105.
- [19] Zeng W, Lao X, Rutherford S, et al. The effect of heat waves on mortality and effect modifiers in four communities of Guangdong Province, China. *Sci Total Environ*. 2014, 482-483: 214-221.
- [20] Cold exposure and winter mortality from ischaemic heart disease, cerebrovascular disease,



1  
2  
3  
4  
5  
6  
7  
8  
9  
10  
11  
12  
13  
14  
15  
16  
17  
18  
19  
20  
21  
22  
23  
24  
25  
26  
27  
28  
29  
30  
31  
32  
33  
34  
35  
36  
37  
38  
39  
40  
41  
42  
43  
44  
45  
46  
47  
48  
49  
50  
51  
52  
53  
54  
55  
56  
57  
58  
59  
60

respiratory disease, and all causes in warm and cold regions of Europe. The Eurowinter Group. *Lancet*. 1997, 349(9062): 1341-1346.

[21] Braga A L, Zanobetti A, Schwartz J. The effect of weather on respiratory and cardiovascular deaths in 12 U.S. cities. *Environ Health Perspect*. 2002, 110(9): 859-863.

[22] Zeka A, Browne S, Mcavoy H, et al. The association of cold weather and all-cause and cause-specific mortality in the island of Ireland between 1984 and 2007. *Environ Health*. 2014, 13: 104.

[23] Rytí N R, Guo Y, Jaakkola J J. Global Association of Cold Spells and Adverse Health Effects: A Systematic Review and Meta-Analysis. *Environ Health Perspect*. 2016, 124(1): 12-22.

[24] Iñiguez C, Ballester F, Ferrandiz J, et al. Relation between temperature and mortality in thirteen Spanish cities. *Int J Environ Res Public Health*. 2010, 7:3196 – 3210.

[25] Xie HY, Yao ZB, Zhang YH, et al. Short-term effects of the 2008 cold spell on mortality in three subtropical cities in Guangdong Province, China. *Environ Health Perspect*. 2013, 121(2):210-216

[26] Kysely J, Pokorna L, Kyncl J, et al. Excess cardiovascular mortality associated with cold spells in the Czech Republic. *BMC Public Health*. 2009, 15, 9:19.

[27] Gasparrini A, Guo Y, Hashizume M, et al. Mortality risk attributable to high and low ambient temperature: a multicountry observational study. *Lancet*. 2015, 386(9991): 369-375.

[28] Analitis A, Katsouyanni K, Biggeri A, et al. Effects of cold weather on mortality: results from 15 European cities within the PHEWE project. *Am J Epidemiol*. 2008, 168(12): 1397-1408.

[29] Liddell C, Morris C, Thomson H, et al. Excess winter deaths in 30 European countries 1980 – 2013: a critical review of methods. *J Public Health*. 2015: v184.

[30] Ren C, Williams GM, Morawska L, et al. Ozone modifies associations between temperature and cardiovascular mortality: analysis of the NMMAPS data. *Occup Environ Med*. 2008. 65, 255–260.

[31] BuckleyJP, Samet J M, Richardson DB. Commentary: Does Air Pollution Confound Studies of Temperature? *Epidemiol*. 2014, 25(2): 242–245.

[32] Ren C, O’ Neill MS, Park SK, et al. Ambient temperature, air pollution, and heart rate variability in an aging population. *Am J Epidemiol*. 2011,173:1013 – 1021.

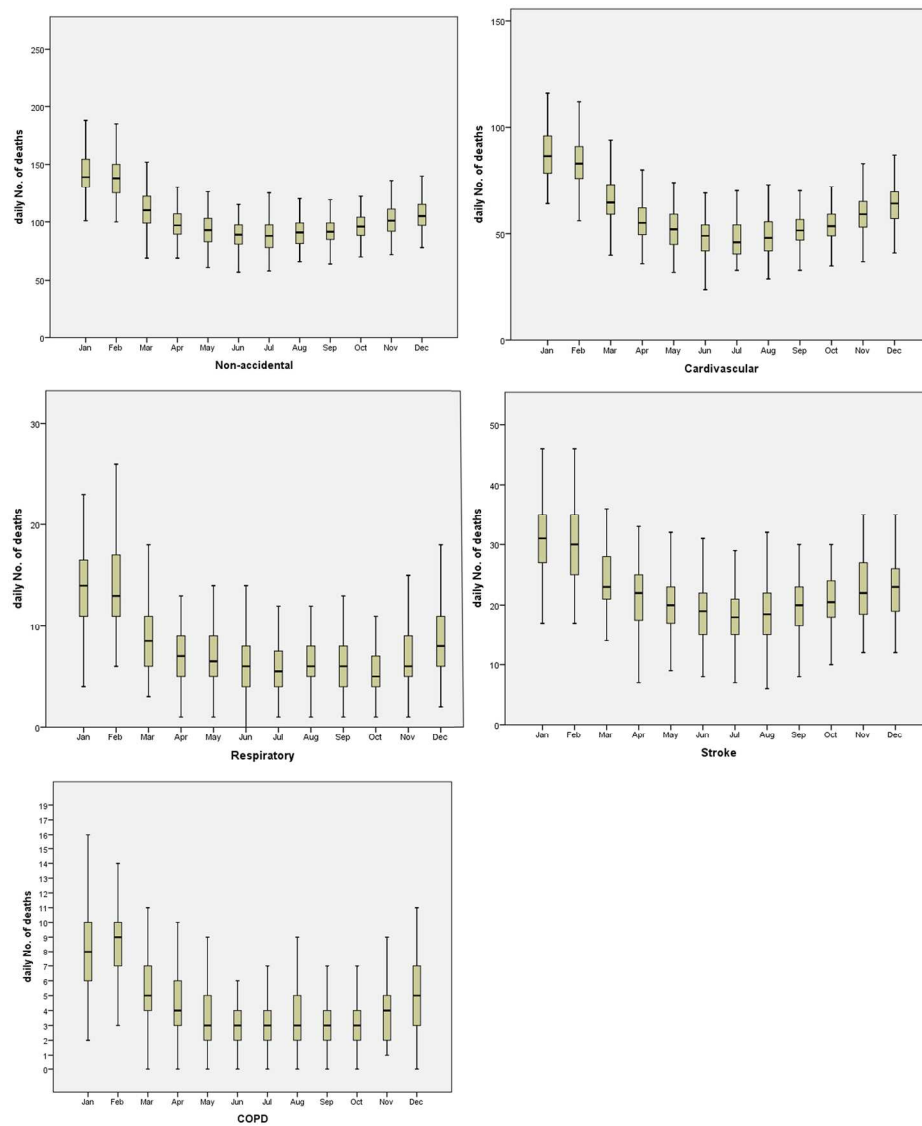
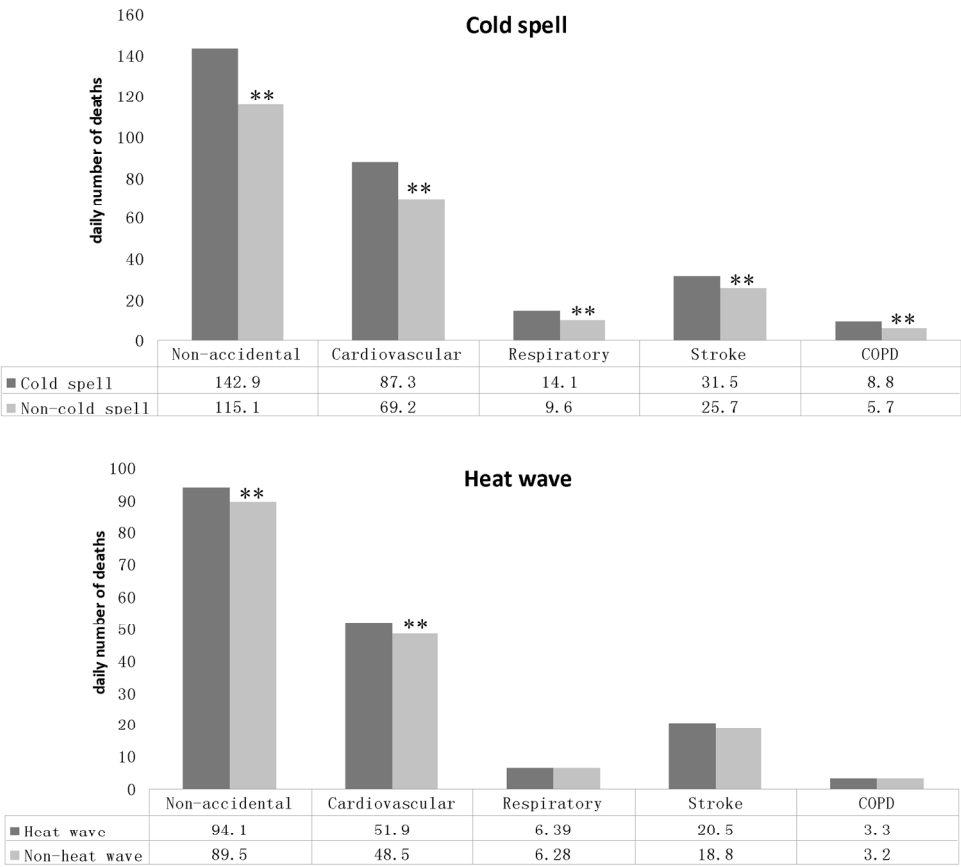
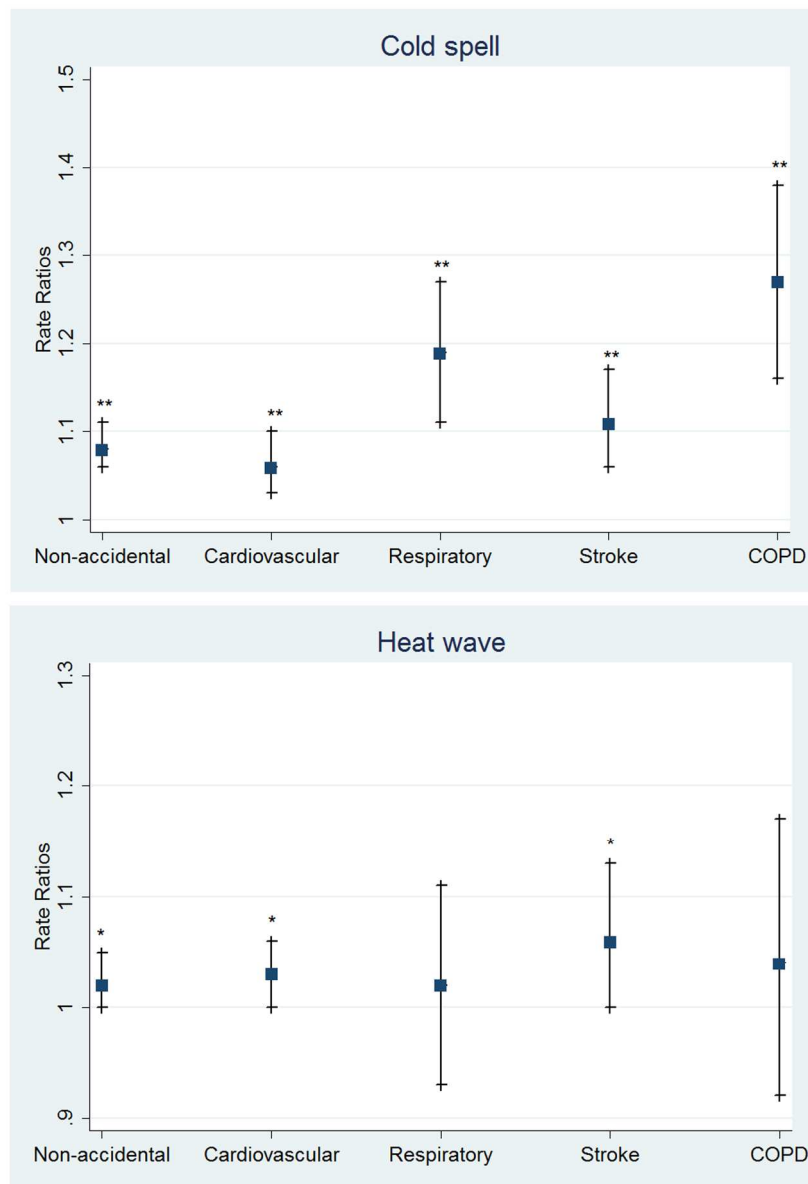


Figure.1. Seasonal distributio  
173x219mm (300 x 300 DPI)



\*\*p < 0.01  
Figure.2. Comparison of the av  
173x199mm (300 x 300 DPI)



\*p < 0.05, \*\*p < 0.01  
Figure.3 RR of cold spells and  
160x219mm (300 x 300 DPI)

Research checklist

	Item No	Recommendation
<b>Title and abstract</b>	1	(a) P1
		(b) P1
<b>Introduction</b>		
Background/rationale	2	P1
Objectives	3	P1
<b>Methods</b>		
Study design	4	P2
Setting	5	P2
Participants	6	P2
		P2
Variables	7	P2
Data sources/ measurement	8*	P2
Bias	9	NA
Study size	10	P2
Quantitative variables	11	P2
Statistical methods	12	P2
		P2
		P2
		P2
		P2

Continued on next page

**Results**

Participants	13*	(a) P3
		(b) NA
		(c) NA
Descriptive data	14*	(a) NA
		(b) NA
		(c) NA
Outcome data	15*	P3
Main results	16	P3-6
		P3-6
		P3-6
Other analyses	17	NA
<b>Discussion</b>		
Key results	18	P6
Limitations	19	P7
Interpretation	20	P7
Generalisability	21	P7
<b>Other information</b>		
Funding	22	NA

# BMJ Open

## The Impact of Temperature Extremes on Mortality : a time-series study in Jinan, China

Journal:	<i>BMJ Open</i>
Manuscript ID	bmjopen-2016-014741.R2
Article Type:	Research
Date Submitted by the Author:	07-Feb-2017
Complete List of Authors:	Han, Jing Liu, Shouqin Zhang, Jun Zhou, Lin Fang, Qiaoling Zhang, Ji Zhang, Ying; University of Sydney, School of Public Health
<b>Primary Subject Heading</b>:	Epidemiology
Secondary Subject Heading:	Public health
Keywords:	PUBLIC HEALTH, EPIDEMIOLOGY, PREVENTIVE MEDICINE

SCHOLARONE™  
Manuscripts

# The Impact of Temperature Extremes on Mortality: a time-series study in Jinan, China

Jing Han<sup>1</sup>, Shouqin Liu<sup>1</sup>, Jun Zhang<sup>1</sup>, Lin Zhou<sup>1</sup>, Qiaoling Fang<sup>1</sup>, Ji Zhang<sup>1\*</sup>, Ying Zhang<sup>2,3\*</sup>

<sup>1</sup>Jinan Municipal Center for Disease Control and Prevention, Jinan, China

<sup>2</sup>Sydney School of Public Health/China Studies Center, The University of Sydney, Sydney, Australia

<sup>3</sup>School of Public Health/Climate and Health Research Center, Shandong University, Shandong, China

\* Corresponding authors. Tel.: +86 531 81278866; Tel: +61 2 91141417

E-mail addresses: zhangji1967@163.com (J.Zhang), ying.zhang@sydney.edu.au (Y. Zhang)

**Objective:** To investigate the relationship between temperature extremes and daily number of deaths in Jinan, a temperate city in northern China.

**Methods:** Data of daily number of deaths and meteorological variables over the period of 2011-2014 were collected. Cold spell/ Heat wave were defined as  $\geq 3$  consecutive days with mean temperature  $\leq 5$ th percentile or  $\geq 95$ th percentile, respectively. We applied a time-series adjusted Poisson regression to assess the effects of extreme temperature on deaths.

**Results:** There were 152150 non-accidental deaths over the study period in Jinan, among which 87607 persons died of cardiovascular disease, 11690 of respiratory disease, 33001 of stroke disease and 6624 of COPD disease. Cold spell significantly increased the risk of deaths due to non-accidental (RR: 1.08, 95%CI: 1.06-1.11), cardiovascular (RR: 1.06, 95%CI: 1.03-1.10), respiratory (RR: 1.19, 95%CI: 1.11-1.27), stroke (RR: 1.11, 95%CI: 1.06-1.17) and COPD (RR: 1.27, 95%CI: 1.16-1.38). Heat wave was most pronounced for deaths of non-accidental (RR: 1.02, 95%CI: 1.00-1.05), cardiovascular (RR: 1.03, 95%CI: 1.00-1.06) and stroke (RR: 1.06, 95%CI: 1.00-1.13). The elderly were more vulnerable during heat wave exposure. The vulnerability to cold spell was for the whole population regardless of age and gender.

**Conclusions:** Both cold spell and heat wave have increased the risk of death in Jinan, China.

**Key words:** Temperature extremes; Mortality; Poisson regression; Time series

**Word count:** 2182

## Strengths and limitations of this study

This study was the first to examine the effects of both cold spell and heat wave on mortality in China of the study area.

A large and recent database with more than 152k mortality data was analyzed to achieve robust results.

We did not include air pollution levels due to data unavailability.

Ecological bias based on population data was inevitable. Generalization of the study findings should be made with caution given that data from one city were included in the study.

## 1. Introduction

The IPCC has already predicted that extreme temperature events will become more frequent and more intense as global mean temperature rises.<sup>1</sup> For example, the heat wave in 1987 of Athens and in 1995 of Chicago caused thousands of deaths.<sup>2</sup> In Europe and Russia, an increase in the occurrence of extreme temperature events has been observed, such as the devastating heat waves in 2003 and 2010.<sup>3-4</sup> Parts of eastern Asia also experienced extremely hot summer in 2010.<sup>5</sup> 2014 North American cold wave event affected parts of Canada and the Eastern United States which broke 100 year low-temperature records in US(<https://www.climate.gov/news-features/event-tracker/polar-vortex-brings-cold-here-and-there-not-everywhere>).



In 2008, southern China experienced a severe continuous cold spell of a long duration, with estimated direct economic losses of more than US \$22.3 billion. This event is considered a once in 50–100 years event.<sup>6</sup> In the summer of 2013, the strongest intensity of heat waves since 1951 occurred in southern China.<sup>7</sup>

Temperature extremes are a threat to human health and are associated with increased mortality risk.<sup>8–9</sup> Temperature-mortality relationship has been noted with the U, V or J shapes with increased mortality at cold and hot temperatures.<sup>10–11</sup> Increasing mortality due to extreme temperatures has been reported in many countries, e.g. Europe, Russia, US, Australia and China.<sup>12–13</sup> There is a lack of studies in developing countries exploring the association between extreme temperature and mortality. Additionally, reported heterogeneity of the effects of extreme temperatures on mortality varies greatly across regions.<sup>6, 14</sup> Limited studies have examined the impacts of extreme temperature on mortality in China and many of previous studies were conducted in subtropical zones of southern China.<sup>15</sup>

Jinan, the capital of Shandong province in Eastern China, is located in a warm temperature zone. Being surrounded by mountains on three sides, Jinan has a unique weather condition with very hot summers and cold winters.<sup>16</sup> However, there has been not a clear picture on the effects of both extreme cold and hot temperatures on mortality in the city, which was not included in the previous publication on weather-mortality in 66 communities in China either.<sup>15</sup> Our previous study in Jinan has found that heat waves significantly increased the risk of mortality and caused 24.88 % excess non-accidental deaths.<sup>17</sup> This study used more recent data to investigate the effect of both heat wave and cold spell on daily number of deaths in Jinan. Furthermore, we have explored vulnerable populations to temperature extremes.

## 2. Materials and Methods

### 2.1. Data collection

Jinan is located at latitude 36° 40'N and longitude 116° 57'E, with six districts, one county-level city, and three counties. Its population was 7067900 in 2014 with an urban population of 4693700 (Shandong Provincial Statistical Yearbook 2015). Jinan has a temperate climate with four well-defined seasons. The city is dry and nearly rainless in spring, hot and rainy in summer, crisp in autumn and dry and cold in winter. The average annual temperature is 14.70 °C and average total annual rainfall is 670 mm (China Meteorological Administration). Due to the mountains to the south of the city, temperature inversions are common, occurring on about 200 days per year.

Mortality data were obtained from the China Information System for Death Register and the Report of Jinan Municipal Centre for Disease Control and Prevention from 1 January 2011 to 31 December 2014. The mortality data were from ten administrative divisions. We classified non-accidental mortality according to the International Classification of Diseases, 10th revision (ICD-10 codes A00–R99). Chronic Obstructive Pulmonary Disease (COPD) (ICD-10 codes J40–J44, J47), cardiovascular mortality (ICD-10 codes I00–I99), respiratory mortality (ICD-10 codes J00–J99) and stroke (ICD-10 codes I60–I69) were examined separately.

Daily meteorological data over the same period, including daily maximum, mean, and minimum temperature and relative humidity, were obtained from the China Meteorological Data Sharing Service System (CMDSSS). We did not include air pollution levels in our model due to data unavailability.

### 2.2. Data analysis

#### 2.2.1. Relationship between daily number of deaths and overall daily mean temperatures

A descriptive analysis was performed to understand the time-series characteristics of the daily number of deaths and meteorological variables over the study period. Given that previous studies have reported a non-linear relationship between temperature and mortality, non-parametric Spearman correlation analysis was performed. Cross-correlation analysis was also performed with relevant lag values given the potential lagged effect of temperature.

2.2.2. Relationship between daily number of deaths and temperature extremes

Analysis of temperature extremes was restricted to the winter seasons (November-March) and summer seasons (May-August) in 2011-2014 in this study. Heat wave was defined as a period of at least 3 consecutive days with daily mean temperature above the 95th percentile (29.0 °C) from May to August during the study period; cold spell was defined as a period of at least 3 consecutive days with daily mean temperatures below the 5th percentile (-3.8°C) from November to March during the study period. We did not investigate the risks due to different characteristics of heat waves and cold spells due to the similar features of these waves observed from this study area.

Independent-sample t test was used to compare the difference of the average number of non-accidental deaths and cause-specific deaths between the cold spell/heat wave exposure days and non- exposure days. Time-series adjusted Poisson regression was applied to quantify the impacts of cold spell/heat wave on daily number of deaths at different lag days. Contributing factors such as long-term and seasonal trends, day of week (DOW), relative humidity (RH) and ambient temperature were controlled in the model as potential confounders. No over-dispersion was detected in our data, and the model used in the analysis can be described as:

$$\text{Log}[E(Y_t)] = \alpha + \beta T_{\min_t} + \eta \text{DOW}_t + \gamma \text{Strata}_t + \lambda \text{RH}_t + \delta \text{ED}_t$$

where t is the day of the observation; Y<sub>t</sub> is the observed daily death counts on day t; α is the intercept; T<sub>min</sub> is mean temperature on day t, and β is vector of coefficients; DOW is day of the week on day t, and η is vector of coefficients; Strata<sub>t</sub> is a categorical variable of the year and calendar month used to control for season and trends, and γ is vector of coefficients. RH is relative humidity on day t, and λ is vector of coefficients; ED(exposure days)t is a binary variable that is “1” if day t was a extreme temperature exposure days(cold spell/heat wave), and δ is the coefficient.

Relative Risks were estimated by the regression. Population vulnerability was examined based on age and gender of deceased cases.

All statistical tests were two-sided and p-values of less than 0.05 were considered statistically significant. Stata12 were used for the analysis.

3. Results

3.1. Relationship between daily number of deaths and overall temperature

There were 152150 total non-accidental deaths over the study period in Jinan; among which 87607 persons (57.5%) died of cardiovascular disease, 11690 (7.7%) of respiratory disease, 33001 (21.7%) of stroke disease and 6624 (4.3%) of COPD disease. The average daily number of deaths observed was 104.1 for non-accidental, 59.9 for cardiovascular, 8.0 for respiratory, 22.6 for stroke and 4.5 for COPD. The average daily mean temperature and mean relative humidity were 14.7 °C (range: -9.4 °C, 34 °C) and 55% (range: 13%, 100.0%), respectively. The 5th and 95th percentiles of temperature were -3.6 °C and 29°C, respectively (Table 1). Additionally, a clear seasonal distribution of daily number of deaths was observed for all categories of mortality with most cases occurring in winter (December-February) and lowest cases in summer (June-August) (Figure.1).

**Table1** Summary of the daily number of deaths and weather conditions in Jinan, China, 2011-2014

variables	mean	STD	minimu m	5th percentile	95th percentile	maximu m
<b>Death</b>						
Non-accidental	104.1	22.4	57	75	149	210
Cardiovascular	59.9	16.5	24	38	93	130
Respiratory	8	4.1	0	3	16	26
Stroke	22.6	6.8	5	13	35	46
COPD	4.5	2.9	0	1	10	19
<b>Weather variables</b>						

Mean temperature	14.7	10.7	-9.4	-3.6	29	34
Mean relative humidity	55	20	13	24	90	100
<b>Temperature(°C)</b>						
Spring(Mar-May)	16	7.4	-8	3.9	26.3	34
Summer(Jun-Aug)	26.5	2.8	16.3	21.6	30.9	33
Fall(Sep-Nov)	15.3	6.3	-8	4.9	23.9	28
Winter(Dec-Feb)	0.6	4.5	-9.4	-6.6	8.5	11.3

**Figure.1.** Seasonal distribution of daily number of deaths in Jinan, China

The cross-correlation analysis showed that all non-accidental and cause-specific deaths were significantly correlated with mean temperature with lagged effects ranging from 7 to 15 days (Table 2).

**Table2** Cross-correlation between mortality and daily mean temperature in Jinan, China

mortality type	Maximum Coefficient	<i>p</i>	Lag time(d)
Non-accidental	-0.656	0.000	15
Cardiovascular	-0.678	0.000	15
Respiratory	-0.551	0.000	14
Stroke	-0.518	0.000	7
COPD	-0.544	0.000	14

### 3.2. Relationship between daily number of deaths and temperature extremes

There were seven cold spells ranging from 3 to 6 days in 2011-2014. The lowest minimum temperature and highest minimum temperature was -12.9°C and -3.2°C respectively. Eight heat waves with a total of 39 days were identified during the study period. The lowest maximum temperature and highest maximum temperature was 33.1°C and 39.1°C respectively (Table 3).

**Table3** Characteristics of cold spells and heat waves in Jinan, China

Cold spells					
Year	Date of start	Duration(d)	Lowest Minimum temperature(°C)	Highest Minimum temperature(°C)	Maximum temperature(°C)
2011	Jan14	6	-11.6	-3.2	3
	Jan22	3	-9	-4.5	5.4
2012	Jan20	5	-10.7	-3.4	4
	Feb1	3	-10.4	-6.1	4.8
	Dec23	4	-11.8	-9.3	0
2013	Jan2	4	-12.9	-9.5	5
2014	Feb9	3	-11.2	-6.8	1.3
Heat waves					
Year	Date of start	Duration(d)	Lowest Maximum temperature(°C)	Highest Maximum temperature(°C)	Minimum temperature(°C)
2011	July22	3	33.4	36.8	25.7
2012	June 17	6	34.7	36.9	22.9
	July 25	6	33.7	36.9	24.7
2013	July6	3	34.5	37.2	22.2
	Aug 4	4	33.1	35.6	22.2
	Aug 11	6	34.6	38.2	21.0
2014	May27	5	36	39.1	20.7
	July 16	6	33.4	37.6	24

There were a total of 72416 non-accidental deaths during winter seasons over the study period in Jinan. Of these deaths, 43698 persons (60.3%) died of cardiovascular disease, 6291 (8.6%) of respiratory disease, 15973 (22.1%) of stroke disease and 3786(5.2%) of COPD disease. A total number of 44729 non-accidental deaths were reported during summer seasons over the study period, among which deaths of cardiovascular disease accounted for 54.4 % (24369), 6.9% (3106) for respiratory disease, 21.1 % (9423) for stroke disease and 3.5 % (1607) for COPD disease. Both cold spell and heat wave were associated with increased mortalities. Cold spell were statistically significant for all examined deaths. Heat wave was most pronounced for non-accidental and cardiovascular mortality but not for the others (Figure 2).

**Figure.2.** Comparison of the average daily number of deaths between cold spell/heat wave days and non-exposure days

The Poisson regression models showed that cold spell caused a significant increase in mortality risk of non-accidental (RR1.08, 95%CI: 1.06-1.11), cardiovascular (RR1.06, 95%CI: 1.03-1.10), respiratory (RR1.19, 95%CI: 1.11-1.27), stroke (RR1.11, 95%CI: 1.062-1.17) and COPD (RR1.27, 95%CI: 1.16-1.38). The risk of deaths related to heat waves increased significantly for non-accidental (RR1.02, 95%CI: 1.00-1.05), cardiovascular (RR1.03, 95%CI: 1.00-1.06) and stroke (RR1.06, 95%CI: 1.00-1.13). Deaths of respiratory (RR1.02, 95%CI: 0.93-1.11) and COPD (RR1.04, 95%CI: 0.92-1.17) also increased during the heat waves, but the impact was not statistically significant (Figure 3).

**Figure.3** RR of cold spells and heat waves on daily number of deaths in Jinan, China

Rate ratios (RR) were calculated as ratios between the death numbers in the cold spell/heat wave days and in the non-cold spell/non-heat wave days

\* $p < 0.05$ , \*\* $p < 0.01$

Cold spell significantly increased risk of non-accidental mortality on both genders and age groups. Heat waves increased risk on both genders. The risk of mortality in elderly people (over 65 years) increased statistically during heat waves, but not in the younger ( $\leq 64$  years) age group (Table 4).

**Table4** Gender and age specific risk of cold spells and heat waves on total non-accidental mortality in Jinan, China

Exposure period	RR of cold spell (95% CI)	RR of heat wave (95% CI)
Gender		
Male	1.09 (1.06-1.12) **	1.03 (1.00-1.07) *
Female	1.12 (1.08-1.16) **	1.04 (1.00-1.07) *
Age		
0-64	1.14 (1.09-1.19) **	0.97 (0.93-1.02)
$\geq 65$	1.08 (1.06-1.11) **	1.03 (1.01-1.06) **

\* $p < 0.05$ , \*\* $p < 0.01$

**4. Discussion**

In this study, we have examined the effects of temperature extremes including both cold spell and heat wave on deaths in Jinan, China from 2011 to 2014. Our results indicate both extreme cold and heat waves could increase the risk of deaths in the study area. The population vulnerability to temperature extremes varies depending on age and gender.

For heat wave, an increased risk of deaths has been found for non-accidental, cardiovascular and stroke mortality. Our result has confirmed the results from our previous study on heat wave and mortality. Moreover, the elderly above 65 years were observed to be more vulnerable during heat waves exposure. This finding is consistent

with previous studies in Europe, Latin America and China.<sup>15,18-19</sup> However, our estimates of increased mortality risk during heat waves are not as high as Ma's study which conducted in 66 communities of China.<sup>15</sup> There are several possible reasons for this. First of all, techniques used to estimate increased risks for mortality varied across the studies. We applied a time-series adjusted Poisson regression rather than a time-series regression model combined distributed lag nonlinear model (DLNM) used in Ma's studies. The DLNM can estimate cumulative effect in the existence of delayed contributions. But they used cumulative excess mortality risk of heat wave only at 0-1 lag days. Instead, we have examined the risk at various lag values. Moreover, Jinan often has particularly very hot summer days with unique geographic and environmental situations. Local residents may have developed adaptive behaviors to heat, which could contribute to a reduced mortality risk.

The underlying factors of the vulnerability are both social and medical. An aging society means higher prevalences of chronic and degenerative diseases. For the elderly, their physiological responses to environment decreased along aging and poor medication interacts with thermoregulation. China is facing the challenges of a rapid growth in the number of old people with the largest elderly population in the world. In Jinan, the elderly above 65 was 750,000 which accounted for 12.31% of population by the end of the year 2014. Giving the large aging population in Jinan, this study has public health implication on improving the public health service for aging people in a changing climate.

Cold spell has significantly increased risk of death compared to non-cold spell periods. This finding is in agreement with previous studies in Europe and Russia. In our study, the significant effects of cold spell were identified on deaths of non-accidental, cardiovascular, respiratory, stroke and COPD. Cold spell effect for cause-specific mortality varies in different regions. In a study of the Eurowinter Group, cold effect was found for respiratory causes but not for cardiovascular disease and ischemic heart disease in warmer countries.<sup>20</sup> In China, a thirty-six communities study found more pronounced cold spell effect for respiratory mortality than for cardiovascular or cerebrovascular mortality.<sup>6</sup> Stronger associations for cardiovascular disease compared with respiratory mortality was observed in US and Ireland.<sup>21-22</sup> In a recent study conducted a meta-analysis showed cold spell was associated with increased mortality from all non-accidental causes, especially from cardiovascular and respiratory diseases.<sup>23</sup> Our findings could be important for public health intervention on people with underlying chronic disease such as cardiovascular, respiratory, stroke and COPD diseases by addressing behavioral risk factors in winter season. Besides, there is a need for specific cold spell prevention plans for public health authority in Jinan, which would enable mortality attributable to low temperatures to be reduced.

One interesting finding from our study is the higher vulnerability to cold among the younger age group (<65 years) compared with the elderly (over 65 years). The finding sounds different from previous studies that reported older people (over 65 years or 75 years) might be the most vulnerable.<sup>24-25</sup> It indicates that population vulnerability to cold spell could vary depending on various study settings. Similar evidence in Ireland that young adult (18-64 years) with respiratory disease might be the most susceptible to cold related deaths.<sup>24</sup> A study conducted in the Czech Republic reported cold spells had the greatest effect on young adult men (25-59 years) with CVD.<sup>26</sup> Occupational exposure might attribute to our finding, given that older people tended to stay indoors during cold days, and thus avoided direct exposure to low ambient temperatures. In addition, adaptive behaviors might be more likely taken by older residents in Jinan because of very cold winters in the history. More research is required to identify underlying reasons of the population vulnerability to cold in Jinan. Climate change, particularly global warming has led to heat and heat wave being a special focus with climate on human health. Cold spell, however, have been given less attention by researchers. Studies have reported that significant increases in mortality during cold spell in different sub-population in Bangladesh, Netherlands, Czech and Moscow. Gasparrini et al. found that the attributable deaths were more pronounced for low than for high temperature in a multicountry study.<sup>27</sup> Additionally, a study using data from 15 European cities demonstrated that cold-related mortality is an important

1  
2  
3  
4  
5  
6  
7  
8  
9  
10  
11  
12  
13  
14  
15  
16  
17  
18  
19  
20  
21  
22  
23  
24  
25  
26  
27  
28  
29  
30  
31  
32  
33  
34  
35  
36  
37  
38  
39  
40  
41  
42  
43  
44  
45  
46  
47  
48  
49  
50  
51  
52  
53  
54  
55  
56  
57  
58  
59  
60

public health problem across Europe. It should not be underestimated by public health authorities because of the recent focus on heat-wave episodes.<sup>28</sup> In UK, excess winter mortality has enjoyed prominent status in many aspects of public policy and research.<sup>29</sup> Our finding has demonstrated that cold spell is as vital as heat waves in Jinan.

Given that climate change will bring more temperature extremes including cold spell, our study has public health implications for policy and practice for government at all levels, as well as community capacity building. Specifically, findings of our study can assist in development of adaptive strategies and policies with a focus on identified vulnerable populations in the community, including the refinement of current public health emergency response plans to focus on both very hot and very cold temperatures. It could also inform the development of clinical guidelines and training programs to doctors in order to improve health service during extreme temperature events, with a better understanding of the pathophysiological mechanisms in mediating heat and cold health effects. Building community resilience could also be supported with better preparation to reduce the number of temperature-related deaths.

Some limitations of the study should be acknowledged. First, the data were only from one city, generalization of the results to other regions should be cautious. However, we also recognize the importance of local studies to assist decision making for local communities. The lessons learnt from Jinan could provide more evidence for other regions with similar conditions in China. Second, air pollution data, e.g. ozone, was not available over the study period. In previous studies, the estimated temperature effects were slightly reduced or not changed when air pollution including ozone was controlled for.<sup>10, 25</sup> Some studies also found a potential interaction between temperature and ozone.<sup>30</sup> However, there are also studies suggesting that the effects of air pollution on mortality could be much smaller than the temperature effects.<sup>31-32</sup> Thus, the relationship that we detected between mortality and the temperature extremes might not be substantially confounded by the effects of air pollution. Third, ecological bias based on population data is inevitable. More studies could be conducted when individual level data, e.g. more detailed age groups, living conditions, health status and socio-economic status of deceased people, are available to be able to detect more detailed distribution of population vulnerability.

**5. Conclusions**

Our results provide more evidence regarding the health impacts of extreme temperatures including cold spell and heat wave. Our study suggests that the cold health effect should not be underestimated in Jinan city. An increasing number and intensity of temperature extremes (cold spell and heat wave) will have a deep impact on health. From the point of view of prevention, multi-discipline cooperation aimed at avoiding or diminishing the effects of temperature extremes need to be carried out.

**Conflict of interest**

The authors declare that there is no conflict of interest.

**Contributors**

JH contributed to the study design, data analysis and drafting of the manuscript. SQL and JZ contributed to data collection, analysis, interpretation of data and wiring the draft. LZ and QLF collected and managed the data sets and contributed to data analysis, manuscript writing and interpretation to policy. YZ and JZ contributed to study design, data analysis and interpretation of results, as well as manuscript writing and dissemination of findings to stakeholders.

**Ethics statement**

The project has an ethical approval from China Information System for Death Register and the Report of Jinan Municipal Centre for Disease Control and Prevention with the permission to use the data from 1 January 2011 to 31 December 2014.

**Data sharing statement**



No additional data are available.

## References:

- [1] Stocker T. Climate change 2013: the physical science basis: Working Group I contribution to the Fifth assessment report of the Intergovernmental Panel on Climate Change. 2014:1535.
- [2] Katsouyanni K T D. The 1987 Athens heat wave. *Lancet*. 1998, 8610(2): 573.
- [3] Barriopedro D, Fischer E M, Luterbacher J, et al. The hot summer of 2010: redrawing the temperature record map of Europe. *Sci*. 2011, 332(6026): 220-224.
- [4] Luterbacher J, Dietrich D, Xoplaki E, et al. European seasonal and annual temperature variability, trends, and extremes since 1500. *Sci*. 2004, 303(5663): 1499-1503.
- [5] Lowe R, Ballester J, Creswick J, et al. Evaluating the performance of a climate-driven mortality model during heat waves and cold spells in Europe. *Int J Environ Res Public Health*. 2015, 12(2): 1279-1294.
- [6] Zhou M G, Wang L J, Liu T, et al. Health impact of the 2008 cold spell on mortality in subtropical China: the climate and health impact national assessment study (CHINAs). *Environ Health*. 2014, 13: 60.
- [7] Gu S, Huang C, Bai L, et al. Heat-related illness in China, summer of 2013. *Int J Biometeorol*. 2016, 60(1): 131-137.
- [8] Guo Y, Gasparrini A, Armstrong B, et al. Global variation in the effects of ambient temperature on mortality: a systematic evaluation. *Epidemiol*. 2014, 25(6): 781-789.
- [9] Huang C, Barnett A G, Wang X, et al. The impact of temperature on years of life lost in Brisbane, Australia. *Nat Clim Change*. 2012, 2(4): 265-270.
- [10] Anderson B G, Bell M L. Weather-related mortality: how heat, cold, and heat waves affect mortality in the United States. *Epidemiol*. 2009, 20(2): 205-213.
- [11] Baccini M, Biggeri A, Accetta G, et al. Heat effects on mortality in 15 European cities. *Epidemiol*. 2008, 19(5): 711-719.
- [12] De' D F, Leone M, Scortichini M, et al. Changes in the Effect of Heat on Mortality in the Last 20 Years in Nine European Cities. Results from the PHASE Project. *Int J Environ Res Public Health*. 2015, 12(12): 15567-15583.
- [13] Huang C, Chu C, Wang X, et al. Unusually cold and dry winters increase mortality in Australia. *Environ Res*. 2015, 136: 1-7.
- [14] Gao J, Sun Y, Liu Q, et al. Impact of extreme high temperature on mortality and regional level definition of heat wave: a multi-city study in China. *Sci Total Environ*. 2015, 505: 535-544.
- [15] Ma W, Zeng W, Zhou M, et al. The short-term effect of heat waves on mortality and its modifiers in China: an analysis from 66 communities. *Environ Int*. 2015, 75: 103-109.
- [16] Zhang Y, Bi P, Sun Y, et al. Projected Years Lost due to Disabilities (YLDs) for bacillary dysentery related to increased temperature in temperate and subtropical cities of China. *J Environ Monit*. 2012, 14(2): 510-516.
- [17] Zhang J, Liu S, Han J, et al. Impact of heat waves on nonaccidental deaths in Jinan, China, and associated risk factors. *Int J Biometeorol* 2016, 60(9):1367-75.
- [18] Oudin åström D, Bertil F, Joacim R. Heat wave impact on morbidity and mortality in the elderly

population: A review of recent studies. *Maturitas*. 2011, 69(2): 99-105.

[19] Zeng W, Lao X, Rutherford S, et al. The effect of heat waves on mortality and effect modifiers in four communities of Guangdong Province, China. *Sci Total Environ*. 2014, 482-483: 214-221.

[20] Cold exposure and winter mortality from ischaemic heart disease, cerebrovascular disease, respiratory disease, and all causes in warm and cold regions of Europe. The Eurowinter Group. *Lancet*. 1997, 349(9062): 1341-1346.

[21] Braga A L, Zanobetti A, Schwartz J. The effect of weather on respiratory and cardiovascular deaths in 12 U.S. cities. *Environ Health Perspect*. 2002, 110(9): 859-863.

[22] Zeka A, Browne S, Mcavoy H, et al. The association of cold weather and all-cause and cause-specific mortality in the island of Ireland between 1984 and 2007. *Environ Health*. 2014, 13: 104.

[23] Rytö N R, Guo Y, Jaakkola J J. Global Association of Cold Spells and Adverse Health Effects: A Systematic Review and Meta-Analysis. *Environ Health Perspect*. 2016, 124(1): 12-22.

[24] Iñiguez C, Ballester F, Ferrandiz J, et al. Relation between temperature and mortality in thirteen Spanish cities. *Int J Environ Res Public Health*. 2010, 7:3196 – 3210.

[25] Xie HY, Yao ZB, Zhang YH, et al. Short-term effects of the 2008 cold spell on mortality in three subtropical cities in Guangdong Province, China. *Environ Health Perspect*. 2013, 121(2):210-216

[26] Kysely J, Pokorna L, Kyncl J, et al. Excess cardiovascular mortality associated with cold spells in the Czech Republic. *BMC Public Health*. 2009, 15, 9:19.

[27] Gasparrini A, Guo Y, Hashizume M, et al. Mortality risk attributable to high and low ambient temperature: a multicountry observational study. *Lancet*. 2015, 386(9991): 369-375.

[28] Analitis A, Katsouyanni K, Biggeri A, et al. Effects of cold weather on mortality: results from 15 European cities within the PHEWE project. *Am J Epidemiol*. 2008, 168(12): 1397-1408.

[29] Liddell C, Morris C, Thomson H, et al. Excess winter deaths in 30 European countries 1980 – 2013: a critical review of methods. *J Public Health*. 2015: v184.

[30] Ren C, Williams GM, Morawska L, et al. Ozone modifies associations between temperature and cardiovascular mortality: analysis of the NMMAPS data. *Occup Environ Med*. 2008. 65, 255–260.

[31] BuckleyJP, Samet J M, Richardson DB. Commentary: Does Air Pollution Confound Studies of Temperature? *Epidemiol*. 2014, 25(2): 242–245.

[32] Ren C, O’ Neill MS, Park SK, et al. Ambient temperature, air pollution, and heart rate variability in an aging population. *Am J Epidemiol*. 2011,173:1013 – 1021.



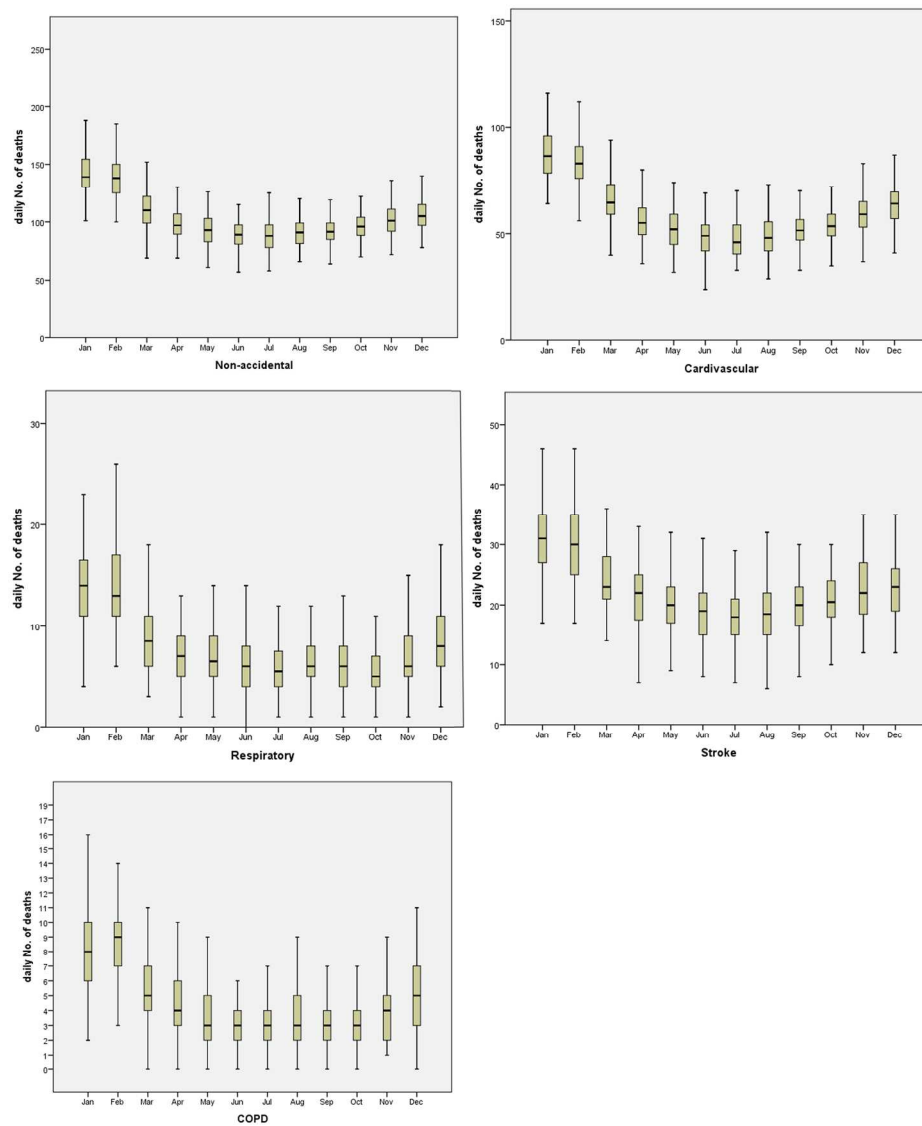
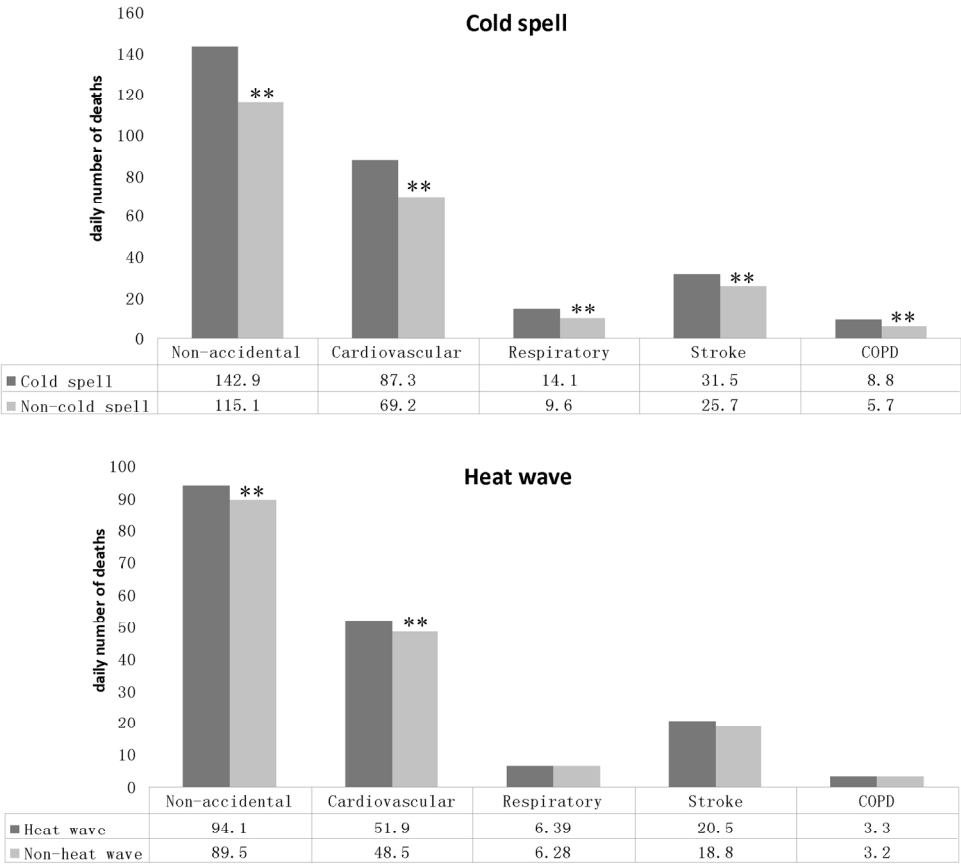
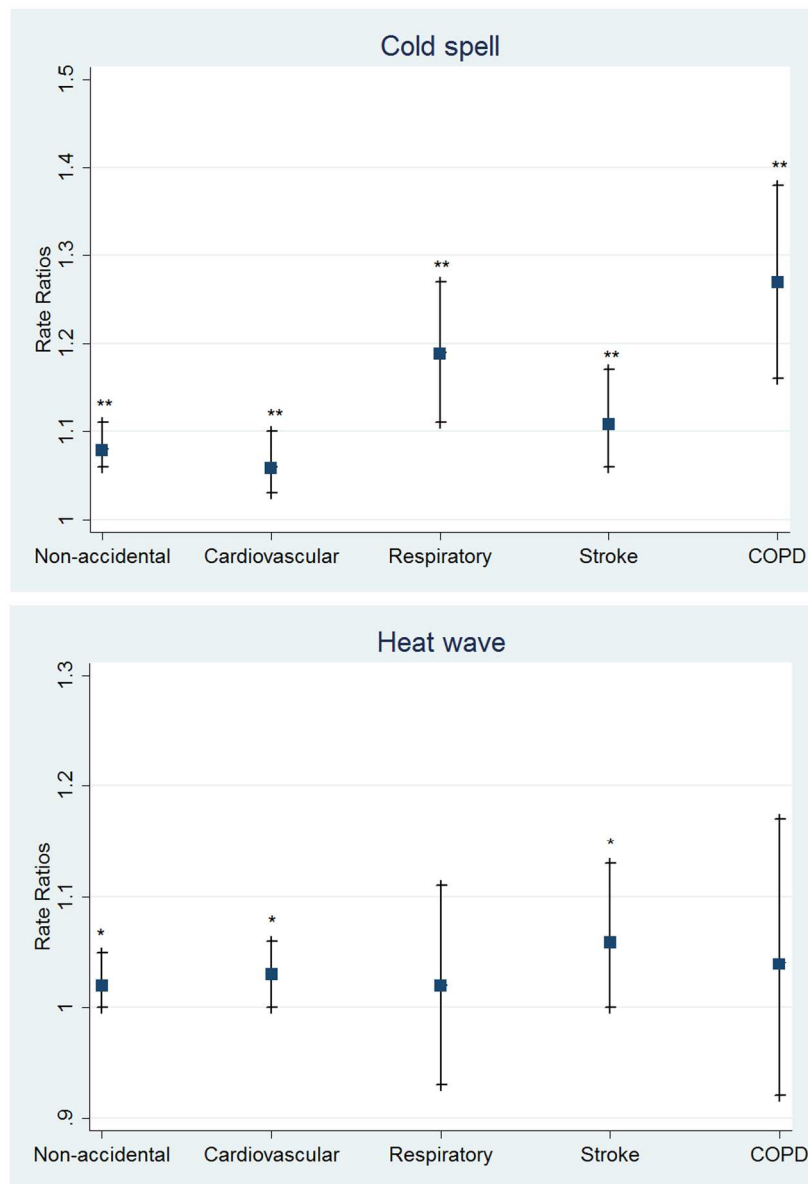


Figure.1. Seasonal distributio  
173x219mm (300 x 300 DPI)



\*\*p < 0.01  
Figure.2. Comparison of the av  
173x199mm (300 x 300 DPI)



\*p < 0.05, \*\*p < 0.01  
Figure.3 RR of cold spells and  
160x219mm (300 x 300 DPI)

Research checklist

	Item No	Recommendation
Title and abstract	1	(a) P1
		(b) P1
Introduction		
Background/rationale	2	P1
Objectives	3	P1
Methods		
Study design	4	P2
Setting	5	P2
Participants	6	P2
		P2
Variables	7	P2
Data sources/ measurement	8*	P2
Bias	9	NA
Study size	10	P2
Quantitative variables	11	P2
Statistical methods	12	P2
		P2
		P2
		P2
		P2

Continued on next page

**Results**

Participants	13*	(a) P3
		(b) NA
		(c) NA
Descriptive data	14*	(a) NA
		(b) NA
		(c) NA
Outcome data	15*	P3
Main results	16	P3-6
		P3-6
		P3-6
Other analyses	17	NA
<b>Discussion</b>		
Key results	18	P6
Limitations	19	P7
Interpretation	20	P7
Generalisability	21	P7
<b>Other information</b>		
Funding	22	NA